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# ACUTE CIRCULATORY FAILURE AS EXEMPLIFIED BY SHOCK AND HÆMORRHAGE[1]

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THE title of this lecture is "Acute Circulatory Failure As Exemplified By Shock and Hæmorrhage." It seems appropriate that this subject should have been chosen since such noteworthy contributions concerning the etiology of shock have been made by one of Dr. Bevan's former associates, Dr. D. B. Phemister. Various terms have been used to designate the condition which follows severe injury. These include traumatic torpor, stupor, prostration without reaction, syncope, collapse, neuroparalysis, *Wundschreck*, *Erschuetterung*, irritation without reaction, exæmia, depressant syndrome, traumatic toxæmia, and traumatic hypodromia. The term that has been almost universally adopted is "shock." According to Groeningen, James Latta in 1795 was the first to employ the term "shock" with the meaning that is now attached to it. Although many objections have been expressed against its use, the clinical picture of shock is clear cut and as long as the term is restricted to this syndrome, I can see no objection to its usage. Before proceeding with a consideration of the earlier views on the subject, two excellent descriptions of the "clinical picture" will be given in detail. The first of these is by John Collins Warren.

A patient is brought into the hospital with a compound comminuted fracture or with a dislocation of the hip joint added to other injuries, where the bleeding has been slight. As the litter is gently deposited on the floor, he makes no effort to move or look about him. He lies staring at the surgeon with an expression of complete indifference as to his condition. There is no movement of the muscles of the face; the eyes, which are deep sunken in their sockets, have a weird, uncanny look. The features are pinched and the face shrunken. A cold, clammy sweat exudes from the pores of the skin, which has an appearance of profound anæmia. The lips are bloodless and the fingers and nails are blue. The pulse is almost imperceptible; a weak, thread-like stream may, however, be detected in the radial artery. The thermometer placed in the rectum registers 96 or 97 degrees F. The muscles are not paralyzed anywhere, but the patient seems disinclined to make any muscular effort. Even respiratory movements seem for the time to be reduced to a minimum. Occasionally the patient may throw about one of his limbs and give vent to a hoarse weak groan. There is no insensibility but he is strangely apathetic, and seems to realize but imperfectly the full meaning of the questions put to him. It is of no use to attempt an operation until appropriate remedies have brought about a reaction. The pulse, however, does not respond; it grows feebler, and finally disappears, and "this momentary pause in the act of death" is soon followed by the grim reality. A postmortem examination reveals no visible changes in the internal organs.

As another example of a case of shock, I will quote the first paragraph from a book entitled, *A Bipolar Theory of Living Processes* by Dr. George Crile (25):

When I was a student in medical school I came for the first time in contact with the dramatic picture of failing bodily energies and death. The patient was young and strong; every organ of the body was sound; he had lost but little blood although both legs

[1]The fifth annual Arthur Dean Bevan Lecture in Surgery, delivered October 20, 1933, before the Chicago Surgical Society and the Institute of Medicine of Chicago.

had been crushed by a locomotive. As I watched him slowly sink into death, the mental and physical prostration, the shrunken, pallid face, the cold sweating skin, the fading pulse, fixed the picture in my mind. Autopsy revealed no lesion in any vital organ. Immediately I planned a research for the purpose of attempting to find what essential mechanism had failed. As I watched the pulse fading so inevitably, I thought that death was due to the want of circulation as the result of heart failure; but what had caused the heart to fail? It was not hæmorrhage, but it appeared to me that failure of the circulation, to whatever it was due, must have been the primary cause of death, and this belief directed the course of my initial studies.

No doubt many others who have studied shock have been prompted to do so because of similar experiences, and this same feeling of a lack of the knowledge requisite for rendering helpful service.

### HISTORICAL RÉSUMÉ

Since man has always been subject to fatal accidents which are usually associated with hæmorrhage, it is probable that blood has been regarded as the vital fluid essential to active existence since early times. This belief (27) explains why red objects as substitutes for blood were used so frequently in the rites of primitive peoples. The dead were buried in red ochre, probably with the object of supplying vitality and of restoring activity to the corpse. Crimson pebbles and other red objects were buried with the dead. In historic times, the Egyptians placed upon mummies a red amulet of carnelian or jasper which typified the blood of the goddess Isis. This was done either to stimulate the functions of the blood or to act as a substitute for the blood that was lacking. The ancient myths that ascribed the origin of trees and plants to blood have their modern counterpart in the custom of the Central Australian natives who swallow blood during severe illness in order to gain renewed vitality (76).

The earliest known pictures of surgical operations are to be found on the door posts of a tomb near Memphis, Egypt (38). These engravings, which were made approximately twenty-five centuries before Christ, portray operations on the extremities and circumcision. With the exception of these procedures and other simple operations, the treatment of wounds constituted the major portion of surgery. It continued to be "wound surgery" in the main until late in the nineteenth century. Modern surgery began only after knowledge of the nature of infections and methods of preventing pain were added to what was known concerning the structure of the human body and methods of controlling loss of blood.

Every branch of surgery is heavily indebted to the information that has been gained in the past and is being gained at present from a study of wounds of various parts of the body. Hippocrates, who said that war is the only proper school for the surgeon, did not describe shock, but he recognized important principles concerning the prognosis in the wounded. He stated (44): "Wounds are very dangerous when there is some large nerve, vein, or artery injured, for the convulsion and the flow of escaping venal or arterial blood prostrates the wounded one and exhausts his strength." Although wounds have occupied the attention of the medical profession for centuries and the study of them has contributed so much to the development of surgery, the cause of death following injury to large masses of tissue has never been explained to the satisfaction of the majority of surgeons and physiologists. This problem has intrigued the imagination of many of the greatest physicians.

Shock was described by Ambroise Paré(45) under the title of "Syncope and Heart Failure." His description corresponds with what is today known as primary shock or collapse. Some of his ideas on the subject are contained in the following quotation.

Syncope is a sudden and strong failure of the faculties and senses, and principally of the vitality, and the sick one remains without any movement. . . . The signs of syncope are when the ill one pales, and when there comes to him a slight sweat, cessation of the movement of the arteries, whereupon soon afterwards he falls to the ground, without any feeling and movement, and becomes seemingly cold throughout, in such fashion that he resembles more a dead man than a live one. Many who fall in syncope, if they are not succorred, die.

According to Seabrook, William Clowes in 1568, Wiseman in 1719, and Garengiot in 1723, recognized shock and attributed it to the presence of some foreign matter in the wound or in the blood.

Shock was usually discussed by the earlier writers under the title of inflammation or irritation. The ideas of John Hunter on the subject are expressed in his work dealing with suppurative inflammation and with gunshot wounds. He stated:

> Nature requires to feel the injury; for where after a considerable operation, there is rather a weak, quiet pulse, often with a nervous oppression, with a seeming difficulty of breathing and a loathing of food, the patient is in a dangerous way. Fever shows powers of resistance; the other symptoms show weakness and sinking under the injury.

Hunter considered the amputation of extremities of soldiers injured at war inadvisable since the operation was a violence added to the injury. He stated:

> In the first case it is only inflammation; in the second it is inflammation, loss of substance, and most probably loss of more blood; as it is to be supposed that a great deal has been lost from the accident, not to mention the awkward manner in which it must have been done.

It is rather difficult to reconcile this view with his further ideas concerning the treatment of injuries. He stated:

> The bark and gentle bleedings, when the pulse begins to rise, are the best treatment that I know of in inflammations that arise either from accidents or operations: One lessens the volume of the blood and the increased animal powers at the time, which makes the circulation more free, so that the heart labours less, and simple circulation goes on more freely; the other gives the blood that which makes it less irritating, makes the blood vessels do their proper offices, and gives to the nerves their proper sensations which take off the fever.

These views should not seem crude when it is remembered that they were expressed approximately 150 years ago.

It is interesting to note the influence exerted by the prevailing practices of the time on the ideas of a man who thought as clearly as did John Hunter. In spite of the statements indicating a remarkably clear perception of the dangers of a diminished blood volume, he yielded to the prevailing opinion and recommended bleeding. One of the most ardent advocates of blood-letting during Hunter's time was Broussais. It is stated (39) that the yearly importation of leeches into France increased from two million to forty million as a result of his influence. Blood-letting was almost abandoned in the middle of the nineteenth century. Doctor Tully said, "The lancet is a weapon which annually slays more than the sword."

Bichat, the creator of descriptive anatomy and a successful French surgeon, did not accept Hunter's theory of inflammation as the essential cause of shock, but entertained ideas which were more in keeping with Paré's conception of circulatory failure. Concerning the causes of death, he stated:

> Here then is the great difference which distinguishes death by old age from that which is the effect of a sudden blow; in the former, life begins to be extinguished first in all the parts and ceases at last in the heart; death extends its empire from the circumference to the center. In the latter, life is extinguished first in the heart, and then in all the parts; in this case it is from the center towards the circumference that death displays its phenomena.

Sir Astley Cooper (81), a pupil of Hunter's, discussed the manner in which injuries produce death in a lecture on "Irritation." He stated:

> Injuries producing fatal consequences destroy life in three different modes. Firstly, when slight, by keeping up a continued constitutional irritation, they gradually wear out the system. Secondly, when more severe, they destroy by occasioning excess of action. Thirdly, the most severe, by shock to the nervous system, causes death, without reaction. Thus, I have seen a person admitted into Guy's Hospital, who had a laden wagon pass over his knee: the bones were crushed, but there was no wound or hæmorrhage, yet the person died a few hours after his admission. I have seen also a man who fell into a vat of hot beer, by which both his lower extremities were scalded, but the body escaped any direct injury. This man's pulse was very small and feeble; his skin was cold; his teeth chattered; reaction took place, and he died in eight hours, notwithstanding stimulants were freely given. I have known a limb amputated for compound fracture, above knee, and the patient die in four hours after, without any reaction; the body was covered with a cold perspiration, and the pulse was scarcely perceptible.

Benjamin Travers, a pupil of Sir Astley Cooper's and senior surgeon to St. Thomas' Hospital, expressed opinions concerning shock that were quite different from those held by his predecessors. These are contained in a book published in 1820 entitled, *An Inquiry Concerning That Disturbed State of the Vital*

*Functions Usually Denominated Constitutional Irritation.* That his ideas differed considerably from those of Hunter, Cooper, and others is shown by the following quotation:

I am far from presuming to gainsay these authorities, but I am disposed to consider apart from fever or constitutional inflammation the nervous affections, to regard them as a distinct order of morbid actions occasionally ensuing upon injuries, upon inflammation, upon the exhaustion attending loss of blood, and upon the admission of noxious matters into the circulation.

Although the fact of death ensuing upon injuries of parts not essential to life, even when unattended by hæmorrhages, and upon operations not usually esteemed hazardous, has not escaped observation; writers and teachers seem to have contented themselves with the bare statement of it, either from an impression that being an equivalent in effect to death on the spot, or being due to an idiosyncrasy moral or physical, the further consideration of the subject in a practical view was unavailing.

It is further stated by Travers:

There is reason to believe that a regular series of impressions and actions maintained between the nervous and muscular systems is indispensable to animal existence, and that an interruption, derangement, or suspension of these is occasionally the result of a sudden and violent shock, mental or corporeal, or of the two combined, which is fatal or recoverable according to the greater or less intensity of the shock and the permanency of the condition from which it originated.

I have called this state "prostration" because the term is descriptive without involving an hypothesis to explain it. It is a state not actually amounting to, but threatening or nearly approaching a cessation of vital action. Whether it be the direct result of the shock or of an exhaustive effort of nature to meet the emergency—as those persons may suppose who look instinctively for final cause and resolve every action into a salutiferous or restorative operation—I will not presume to decide; but it would be utterly subversive of my notion of the case to suppose that nature is in a condition to make any arrangement for her "own relief."

Travers did not agree with Hunter, Cooper, Broussais, and others concerning the value of blood-letting. He said:

The custom of letting blood indiscriminately after injuries is so irrational, that the authority of long-established customs forms no excuse for it. Prophylactic blood-lettings may be proper in certain cases, as in threatened apoplexy, or where hæmorrhagic conditions prevail in parturient women, etc., but they are seldom admissible where injuries have been inflicted. I have seen a practitioner tie up the arm of a person to bleed him after a fall, in a pale cold stun, in which the pulse could scarcely be felt at the wrist. I have known operators permit a large artery to bleed before tying it, in amputations unexpectedly performed on very robust subjects. It is easy to see the motive of such operators, but it is an erroneous pathology, and a dangerous practice; the effects attending upon loss of blood are peculiar, and the reduction of strength by these means has no analogy whatever to that which is brought about by chronic disease, and renders the effects of operations less formidable.

I have quoted from the writings of Benjamin Travers at length because his ideas concerning shock, particularly as regards the treatment, were far in advance of his time, and, in fact, they are more sound than many opinions that have been expressed subsequently.

An interest in the prevention of shock was expressed by Larrey, the distinguished military surgeon, who was characterized by Napoleon as the most virtuous man he had ever known (17). He emphasized the need for the evacuation of the wounded from the field of battle and he effected a marked improvement in the ambulances which were in use at that time (54).

During the last third of the past century, there appeared numerous publications on the subject of shock. The important experimental work of Goltz will be referred to later. Weir Mitchell, who together with Morehouse and Keen observed many nerve lesions during the Civil War, attributed shock to a reflex disturbance, or in some cases, paralysis of the centers. Le Gros Clark defined shock as follows:

The peculiarity of shock, then, is this vital depression, generally sudden, which follows the exciting cause, whatever that may be, and which is marked by the influence thus exercised primarily on the nerve centers and heart; and secondarily, by implication or sympathy, and necessarily through the intervention of nerves, on the organs of respiration, of assimilation and secretion, and on the senses.

Samuel D. Gross defined shock as a rude unhinging of the machinery of life. He believed it to be a depression of the vital powers due in the main to a loss of innervation. Shock and hæmorrhage were contrasted by him as follows:

Shock bears, in effect, the same relation to the nervous system as syncope to the vascular; in the one case the result is caused by a diminution of

nervous fluid, in the other by a diminution of blood; in both, the consequence is more or less prostration, with perturbation of mind and body, extremely variable as to intensity and duration. . . . When blood flows away in a mighty and overwhelming torrent, the person dies, and life is then said to be destroyed, as it certainly is, by the excessive sanguineous drainage. But in shock, the same effect may happen, and yet the body be literally surcharged with blood, not a single drop, perhaps, having been spilled in the accident causing the fatal result. Thus, of the two fluids, the nervous is, in every respect, the more important, because the more essential to life; and its disturbance is, therefore, a more frequent cause of death.

Billroth, who was among the first in Germany to devote particular attention to shock, ascribed it to a molecular disturbance of the brain. Blum attributed it to an arrest of the heart's action due to reflex irritation of the vagus nerve. Savory described shock as follows: "Death from shock, then, is the result of a sudden and violent impression on some portion of the nervous system acting at once through a nerve center upon the heart and destroying its action." It was Savory who made the often quoted remark that, "Action involves exhaustion, and repose is needed for repair. The greater the effort, therefore, the greater the exhaustion." Jordan in "The Hastings Lecture on Shock" defined it as a peculiar condition of the animal system, characterized by depression of all its functions, the result of a powerful impression applied to the nervous centers, or to a portion of the peripheral nervous system. Concerning the prevention of shock, he stated:

If I were going to have my thigh amputated, without the protection of long disease, I would ask that ether should be given to me many hours before the operation, that I might approximate as nearly as possible to early infancy, the stupidity of prolonged disease, or the hybernation of animals. The best protection against shock is a state similar to shock, namely, anæsthesia to the extent of sleep for many hours.

The most significant of the early experimental work on shock was that of Goltz (39, 40). He found that repeated blows on the viscera of the suspended frog caused reflex inhibition of the heart through the vagus and a lessening of vascular tone generally throughout the body and especially in the abdominal cavity. Goltz produced by this method what is known as "primary shock" or "collapse" and little has been added to our information concerning the condition since his results were reported. The explanation which he gave seems to be entirely satisfactory. Fischer, reasoning from the experiments of Goltz, assumed that traumatic, or secondary shock is due to vasomotor paralysis resulting in the accumulation of the greater part of the blood in the splanchnic area and an anæmia of other parts of the body. The vascular disturbance was considered the primary cause and all other symptoms were secondary phenomena. It might be well at this point to define the present usage of the terms, "primary shock" and "secondary shock." Primary shock, or collapse, refers to the condition in which a decline in the blood pressure and the appearance of the symptoms of shock are noted immediately following the injury. In secondary shock, the time interval separating the injury and the appearance of symptoms is usually an hour or more. In some instances, primary shock may progress into the secondary type.

Groeningen believed that severe injury resulted in shock because of damage to the medulla and spinal cord. He took exception to the theory of vasomotor paralysis as enunciated by Fischer and showed that Goltz, himself, did not regard the condition he studied as shock, but rather as syncope or fainting. In rabbits subjected to the experimental procedure used by Goltz, Groeningen was unable to demonstrate anæmia in the peripheral vessels. In rabbits dying as a result of trauma, he found that the abdominal arteries and veins were empty. In discussing the theory of vasomotor paralysis, John Collins Warren stated: "It has certainly been the writer's experience that the symptoms of shock are not accompanied by any marked change in the blood supply to the abdominal vessels."

### REVIEW OF MORE RECENT LITERATURE

The views of Crile (24) on the subject of shock have been extensively quoted throughout the world. As a result of many experiments, he came to the conclusion that shock is due to exhaustion of the vasomotor center

consequent to overstimulation. According to Crile, shock may be produced by varied causes such as fear, worry, physical injury, infection, etc. This is the kinetic view of shock, that is, that exhaustion is the natural result of overaction. The so called "shockless operation" where worry, fear, and rough manipulation are reduced to a minimum, has been advocated by Crile. As a result of his teachings, the incidence of shock following operations has been greatly reduced and the treatment of shock has been improved. Halsted, Carrel, and others have made noteworthy advances in this respect. On the other hand, many of the experimental findings and theories of Crile have not been supported by the work of Seelig and Lyon (74), Forbes and Miller (33, 34), Dolley (28), Erlanger, Gesell, and Gasser (29), Burch and Harrison (19), and Kocher (53). Porter (65, 67, 68) stated that shock is not due to an exhaustion or depression or inhibition of the vasomotor cells. In an excellent paper entitled, "The Peripheral Origin of Surgical Shock," Mann (57) stated: "It is impossible to reduce the anæsthetized animal to a state of shock by any degree of sensory stimulation, provided all hæmorrhage is prevented and its abdomen is not opened."

Mansell-Moullin assumed that the vasomotor changes in shock were produced by inhibition rather than by simple reflex paralysis. Howell divided shock into the cardiac and vascular types. He assumed that both types were due to an inhibition of the centers in the medulla, that is, an inhibition of the tone of the vagus center caused the rapid heart rate and inhibition of the vasomotor center lead to vascular shock. Meltzer subscribed to the inhibition theory. He stated, "On the basis of these considerations, I venture the assumption, which is not new, that the various injuries which are capable of bringing on shock, do so by favoring the development of the inhibitory side of all the functions of the body."

The possible relationship of fat embolism to shock has been suggested by many writers. The literature on the subject was thoroughly reviewed by Warthin in 1913. Groeningen popularized this view by calling attention to the reported cases in which fat embolism following injuries had supposedly resulted in death. He stated, however, that the symptoms following fat embolism must not be confused with those of shock. Porter (66) in 1919, stated that shock resulting from emboli of fat is not due to embolism of the lungs but rather of the vasomotor region.

Two theories have been offered as to the relationship of the adrenal glands to the state of shock. One maintains that it is due to overactivity of the adrenal glands and the other states that it is due to exhaustion. Bainbridge and Trevan (60) and Erlanger and Gasser (31) produced shock by the injection of large amounts of adrenalin. Freeman (37) has recently caused a diminution in the blood volume by the injection of smaller amounts. Some observers have found that the adrenin content of blood is increased while others have noted no alteration. Mann (56) found that total excision of the adrenals does not reproduce the phenomena of shock. The evidence was summarized by Cannon (20) as follows: "Neither the suggestion of overactivity nor the suggestion of underactivity of the adrenals has sufficient evidence in its favor to warrant attributing shock to the adrenal glands."

The suggestion was made recently by Swingle, Pfiffner, Vars, Bott, and Parkins (78) that the signs and symptoms of adrenal insufficiency, and of traumatic or secondary shock, are possibly due to one and the same thing, namely, failure of the blood volume and blood-diluting regulating mechanism, the adrenal cortex. As has been pointed out by Freeman (36), convincing evidence that the two conditions have a common etiology has not been presented.

It has been suggested that shock is due to acidosis or decrease in the alkaline reserve. Dale and Richards (70) found that the carbon dioxide capacity of the blood can be reduced to a low level without causing permanent changes in the blood pressure. A prolonged low blood pressure from any cause is associated with a reduction in the alkali reserve, but it is a result rather than the cause of the decline in blood pressure.

Yandell Henderson, in 1908, suggested that shock is due to acapnia or excessive respiration, and this theory has been elaborated by

him in an extensive series of papers since that time. He stated that pain, sorrow, fear, and operation cause excessive respiration, this reduces the carbon dioxide content of the blood, and other changes ensue. Many writers, including Groeningen, Clark, Mitchell, and Cannon have noted that the severely wounded do not immediately experience severe pain. The respiratory rate in the wounded is usually increased, but the respirations are shallow. Vigorous hyperpnœa is rarely observed. Cannon (21) summarizes the evidence in regard to the acapnial theory as follows:

> As the foregoing discussion has revealed, none of the relations between acapnia and shock, which are postulated by the theory are fixed—pain and the excessive breathing required for acapnia are commonly absent, shock may exist without acapnia and acapnia may exist without shock, and the low carbon dioxide content of the blood in shock can be accounted for as the result of the low blood pressure, not as its cause.

An important advance in the development of the present conception was made in 1879, when Mapother in an address before the Surgical Society of Ireland stated that the most marked physical change caused by shock was a contraction of the arterioles. He assumed that the dilator nerves were paralyzed. In regard to the theory of vasoconstriction, Malcolm stated: "To sum up: The theory that the vessels are intensely contracted during shock offers a full solution of all the difficulties that I have pointed out as arising when the vessels are assumed to be paralyzed." Boise maintained that the essential cause was sympathetic irritation, manifested mainly by tonic contraction of the heart and arteries. According to Starling the hypertonicity of the arteries and the hypotonicity of the muscles in shock result in a slow flow of blood through the muscles and in an accumulation of blood there with a decrease in the circulatory blood volume. Erlanger and his associates (30) produced vasoconstriction and a decrease in the blood volume by several different methods and noted that the capillaries and venules of the intestinal villi were distended with red blood corpuscles. As a result of these and other investigations, it is almost universally believed at present that secondary shock is associated with vasoconstriction and with a decrease in the blood volume. It is only in the terminal stages that the constriction is replaced by dilatation. Convincing evidence that the blood volume is diminished was furnished by Keith in 1919. As a result of these findings, most of the theories that have been discussed became untenable.

During the World War, committees were appointed in various countries for the purpose of studying shock and many important findings resulted from their work. They are summarized in Cannon's excellent monograph (20) entitled *Traumatic Shock*. As a result of many experiments by various workers and of clinical observations notably by Quénu, the toxæmia theory was formulated. The most often quoted experiments are those that were performed by Cannon and Bayliss (22) in which shock was produced by traumatizing one of the posterior extremities of anæsthetized cats. They found that there was not a sufficient loss of blood into the injured area to account by itself for the decline in blood pressure. Section of the spinal cord in the upper lumbar region, in some experiments, showed that the fall in blood pressure was not due to any general effect of the trauma on the circulation, brought about by nervous agencies. The decline in blood pressure could not be explained on the basis of fat embolism or acapnia or acidosis. It was assumed that the continued fall in blood pressure was due to the absorption of some depressant substance from the injured area into the general circulation. The effects of injecting histamine and of traumatizing muscles were compared in various manners and it was believed that the hypothetical depressant produced by injuring muscles was either histamine or some closely related substance.

Before proceeding with a consideration of recent studies, I will attempt to summarize briefly the more important points that have been brought out thus far. Primary shock refers to the state of collapse that follows immediately the receipt of an injury. A satisfactory explanation for this condition seems to have been obtained by Goltz (39, 40) in experiments in which it was found that the initial alteration in the circulatory system was

vasodilatation. Secondary shock refers to the type in which the interval separating the injury and the development of unfavorable symptoms is usually an hour or longer. It has been in an effort to explain this condition that most of the theories have been advanced. Perhaps the most divergent views have been expressed by those who maintain that shock is associated with a general relaxation of the vessels and those who state that it is accompanied by vasoconstriction. Evidence of a convincing nature has been offered to show that secondary shock except in the terminal stage is associated with vasoconstriction. The proven facts in the case are that it is accompanied by a diminution in the blood volume and a decrease in the blood pressure. As a result of these findings, most of the theories have become untenable. During the past 15 years, the toxæmia theory has been rather generally accepted. This theory differs from the others which consider a diminution in blood volume, vasoconstriction, and capillary congestion as the essential disturbances in secondary shock in that evidence as to the initiating agent is suggested. It has in common with the other theories the fact that no initiating agent has actually been demonstrated.

### A CONSIDERATION OF SHOCK DUE TO (1) UNCOMPLICATED HÆMORRHAGE AND (2) TRAUMA TO MUSCLES

For a detailed discussion of recent contributions to our information concerning shock, I have chosen to consider in the main the results of experiments in which shock was produced in some instances by the removal of blood and in others by injuring muscles. If the results of experiments are to have a clinical application, it is necessary that the general phenomena that are produced should be closely similar to those that are observed in patients. I think that the studies which are to be reported meet this requirement.

The results of the earlier experiments of Smith, of Phemister and Handy, and of Blalock and Bradburn (13), which will not be described in detail here, did not lend support to the hypothesis that traumatic shock is caused by a toxin. These results prompted Parsons and Phemister and myself (6) to repeat the experiments of Cannon and Bayliss (22) which contributed the main evidence for the toxæmia theory. Injury was produced by striking one of the posterior extremities of deeply anæsthetized dogs many blows with a hammer. It was observed that the swelling which followed the injury was not limited to the area directly traumatized, but extended to the groin and flank. Cannon and Bayliss performed the amputations by symmetrical incisions across the upper thighs in their experiments in which they determined the local loss of blood into the injured area. Hence, it seemed that their amputations had not been performed at sufficiently high levels if the entire loss of fluid into the injured tissues was to be determined. In both my experiments and those of Phemister and Parsons, the amputations were performed above the site to which the swelling extended, and the difference in the weights of the injured and non-injured extremities was determined. This difference indicated the loss of approximately one-half of the total blood volume into the injured extremity and it was sufficiently great to account by itself for the decline in blood pressure. These experiments were of approximately the same duration as those of Cannon and Bayliss and similar anæsthetics were used. Parsons and Phemister found that a dilution of the blood remaining in the vessels followed trauma to an extremity, while an increase in the concentration of the red blood cells was usually noted in my experiments (6). This variation in the results was probably due to differences in the severity of the trauma. Very severe trauma with the associated rupture of large vessels results in the loss of blood of approximately the same composition as it exists in the blood stream and a dilution of the remaining blood occurs. Milder trauma causes the loss of a greater proportion of plasma than of red cells and a concentration of the blood occurs.

Many other experiments (6) of a different nature have been performed. If the femoral artery was isolated in the groin and a tourniquet was placed tightly around the upper thigh, compressing all structures except the artery, it was found that severe trauma distal

to the tourniquet caused the death of the animal. Here also the difference in the weights of the two extremities indicated that the decline in pressure was due to the local loss of fluid. Parsons and Phemister found that injury to an extremity, the femoral vein of which had been ligated, resulted in more rapid swelling and fall in pressure than was the case when the vein was not ligated. In other experiments (6) which I performed, the femoral artery and vein were exposed in the groin, the vein was occluded by a bulldog clip and a tourniquet which constricted all of the structures of the thigh except the artery and vein was placed beneath the vessels. Removal of the clip from the vein did not cause a decline in blood pressure in experiments in which gross injury was or was not produced. When the arterial inflow and the venous outflow of an extremity were entirely occluded, gross trauma to the extremity did not produce a decline in the blood pressure. The transfusion of blood from one dog in which a low blood pressure had been caused by trauma to an extremity to another dog in which a low blood pressure had been produced by a loss of blood, either outside the body or into the tissues, resulted in an elevation of the blood pressure of the recipient. No evidence was obtained in these experiments that a histamine-like substance was responsible for the decline in blood pressure following severe injury to an extremity. Parsons and Phemister concluded that reflex vasomotor paralysis or exhaustion did not account for the circulatory failure, since intensive stimulation of somatic nerves produced elevation instead of fall in blood pressure, and equal amounts of traumatism to denervated and innervated extremities produced the same amount of fall in pressure in each. Freedlander and Lenhardt have confirmed these results. I have recently performed experiments (10) similar to those that have been described, using spinal anæsthesia instead of ether or barbital. The results were almost identical with those that were obtained when ether or barbital was used.

In the experiments referred to thus far, the average time between the production of trauma and the advent of death was approximately 3 hours. Although these experiments were of the same duration as those of Cannon and Bayliss, it is believed that they were not sufficiently long to rule out the possible action of all protein decomposition products. Other experiments (8) were therefore performed in which this objection was partially overcome by decreasing the severity of the trauma and hence increasing the survival period of the animals. The length of these experiments was limited because the anæsthesia was necessarily profound. The average duration was 32 hours. The fluid that escaped into the tissue spaces at the site of injury was found by Beard and Blalock (1) to have almost exactly the same composition as the plasma in the blood vessels. It might be remarked here that the fluid lost locally as a result of intestinal trauma or burns is also blood plasma. It is important that the protein content of the blood plasma and of the lost fluid are approximately the same because protein is the constituent that maintains to a large degree the osmotic pressure in the blood vessels. The quantity of fluid that had escaped into the injured extremity was determined following death. The results of these experiments were compared with those obtained in other studies (48) in which death was produced by the removal of plasma from the blood stream. This comparison showed that the decrease in blood volume as a result of the loss of plasma into the injured tissue spaces was sufficient to account for the decline in blood pressure. Similar results have been obtained in other experiments of rather short duration, performed under profound anæsthesia. In some of these (7) the intestines were traumatized and in others (9), large areas of skin were burned. In all of these studies, there was a marked increase in the concentration of the red blood cells.

The relative absorptive powers of traumatized and normal tissues were determined in experiments (26) in which phenolsulphonephthalein or strychnine were injected into anæsthetized dogs. It was found that the substances were absorbed very slowly from the tissues of an injured extremity. The rate was more rapid when the injections were made into the uninjured tissues of either normal dogs or dogs which had had an extremity

traumatized. Underhill, Kapsinow, and Fisk found that absorption from a burned area is much slower than it is under normal conditions.

Further evidence as to the mechanism of the production of shock was obtained in experiments in which the output of the heart and the blood pressure were determined frequently during its development. When hæmorrhage was produced by the slow removal of blood from a large vessel, it was found (5) that the output of the heart diminished considerably before a definite alteration in the blood pressure took place. Trauma to an extremity (49) was followed by alterations similar to those produced by hæmorrhage. On the other hand, following the injection of histamine, the blood pressure declined first and the cardiac output subsequently. Primary shock (10), the introduction of large amounts of novocain into the spinal canal (18) and bilateral adrenalectomy (11) are associated with alterations in the cardiac output and blood pressure similar to those that are produced by the injection of histamine. Trauma to the central nervous system (12) is usually accompanied by a simultaneous decline in the cardiac output and blood pressure. The only point which I wish to emphasize here is that uncomplicated hæmorrhage and trauma to an extremity are both associated with, first, a decrease in the output of the heart followed by a decline in the blood pressure, while the alterations appear in the reverse order as a result of the injection of histamine.

Roome, Keith, and Phemister performed experiments in which the blood pressure was reduced to a shock level by various procedures such as the removal of blood, trauma to an extremity, the injection of histamine, hyperventilation, the introduction of novocain into the spinal canal, and the production of anaphylactic shock. The quantity of blood that it was necessary to remove in order to cause death was then determined. It was found that the removal of a very small amount of blood resulted in death in the experiments in which a low blood pressure had been produced by hæmorrhage and in those in which an extremity had been traumatized. It was necessary to remove much larger quantities in the experiments in which a decline in pressure had been produced by other means.

Observations (10) of a somewhat similar nature were made recently in the course of some of my experiments. The painless death of a large number of dogs was produced by methods which included the removal of blood, trauma to an extremity, the injection of histamine, the injection of acetyl-choline, and the introduction of fluid under pressure into the pericardial cavity. Immediately following death, the pleural and peritoneal cavities were opened widely. After the attachment including the blood supply of the various organs was cut across, the blood which drained freely from them, without pressure being exerted, was allowed to flow into the cavities. The organs were then removed. The amount of free blood remaining in the pleural and peritoneal cavities was determined. Approximately the same quantities of blood were recovered in the experiments in which death was produced by hæmorrhage and by trauma to an extremity. More than twice as much blood was present in the cavities in the experiments in which death was caused by other means.

The general belief is current that shock and hæmorrhage are very different phenomena. It is quite true that they may be in certain instances. As an example of this belief, the following paragraph from a recent editorial in the *Journal of the American Medical Association* (51) is quoted:

> A recent paper[1] indicates that two criteria are available to distinguish between shock and hæmorrhage: In shock the blood becomes more concentrated, as shown by specific gravity, hæmoglobin and erythrocyte count; following hæmorrhage, dilution of blood occurs. In shock there is widespread capillary dilatation of the viscera, congestion accompanied by œdema, and petechial hæmorrhages; following hæmorrhage the tissues are anæmic. The differentiation of hæmorrhage and shock is of more than academic importance. It is well known that recovery follows the introduction of physiologic solution of sodium chloride into the circulation of patients suffering from the simple loss of blood. The futility of this procedure in shock has been proved beyond question. The increased permeability of the capillaries, which is a characteristic feature of shock, allows saline solution to escape readily into the tissues. Solutions containing acacia or dextrose have

[1]Refers to paper of Moon, V. H., and Kennedy, P. J. Pathology of shock. Arch. Path., 1932, xiv, 360.

been found more effective than saline solutions but not so effective as transfusion of blood. Even the latter is ineffective in profound shock.

In other words, it is stated that shock is associated with an increase in the concentration of the red blood cells, with no response to the transfusion of blood and with capillary congestion and hæmorrhage in the tissues. On the other hand, hæmorrhage is associated with a dilution of the red blood cells, with a favorable response to transfusion, and with an anæmic appearance of the tissues. Evidence will be presented which shows that some of these statements are erroneous.

Experiments (10) were performed with local anæsthesia on dogs in which the blood pressure was gradually reduced to a low level by the slow withdrawal of blood from the femoral artery. After having produced a sustained decline in the pressure to approximately 70 millimeters of mercury, the animal was allowed to die without having further blood removed. The desired condition was to have the blood pressure remain at a low level as long as possible preceding death. Usually, death occurred approximately an hour after a sustained reduction in the pressure had been obtained. Capillary congestion and hæmorrhage were noted in some of the organs at autopsy. An increase in the concentration of the red blood cells occurred in a few of the experiments.

A low blood pressure of longer duration was produced in other experiments (10). The pressure was reduced by the removal of blood from the femoral artery and death was delayed by the introduction of blood by the direct method from a suitable donor. If the blood pressure rose above 70 millimeters of mercury, further blood was removed. If death seemed imminent, a small quantity of blood was withdrawn from the donor and injected intravenously. In this manner, the blood pressure was maintained at a low level for several hours before death occurred. No evidence that the blood was incompatible was observed. The blood pressure records in these experiments were quite similar to those that were obtained when an extremity was traumatized. The clinical picture of shock in patients was re-duplicated to a large extent in these experiments. Apathy, pallor, a weak, thready pulse, a low blood pressure, and vomiting were observed. Dogs do not have sweat glands and hence sweating was not a part of the picture. All of the animals died despite the fact that more blood was introduced than was removed. In other words, after the blood pressure remained at a low point for several hours, transfusion was without benefit. An increase in the concentration of the red blood cells was found in all experiments. Capillary congestion and hæmorrhage and necrosis were present in many of the tissues of the body. Particularly striking was the presence of free blood in the lumen of the intestinal tract. Previous observers have described the effects of an inadequate blood supply on the central nervous system.

Thus, it is to be noted that an increase in the concentration of the blood, a negative response to transfusion, and marked alterations in the tissues of the body can be produced by hæmorrhage, and that they are not peculiar to traumatic shock.

In the care of patients, one rarely observes as a result of hæmorrhage a low blood pressure that persists for several hours. If blood is lost to the outside from a large vessel such as the femoral or carotid artery, usually either early death occurs or the bleeding is controlled. If early death occurs, it is only natural that the tissues of the body should appear anæmic at autopsy. If the bleeding is controlled, usually the blood volume is increased by the withdrawal of fluid from the tissue spaces into the blood stream or fluid is introduced artificially and the blood pressure rises. On the other hand, when whole blood or blood plasma are lost from many small vessels into the tissue spaces of an injured extremity, the decline in the blood pressure is slower and the duration of the low blood pressure is longer because the speed with which the fluid escapes is governed largely by the number and size of the vessels and by the relationship between the pressure in the blood vessels and in the tissue spaces. As the pressure in the blood vessels decreases and as the pressure in the tissue spaces increases, the escape of fluid at the site of injury is retarded. Since the blood pressure declines slowly and

remains at a low level for a considerable time preceding death following trauma to large masses of muscle, all of the tissues of the body are partially deprived of blood and oxygen during this time and alterations such as capillary hæmorrhage and congestion take place in them. Hæmorrhage from a large blood vessel is usually associated with a dilution of the red blood cells while trauma to tissues is usually associated with a concentration. In the former instance, the fluid that is lost is whole blood. If the loss of blood is stopped, a dilution of the remaining red blood cells occurs as the result of the passage of fluid from the tissue spaces into the blood stream. On the other hand, the fluid that escapes into the spaces following trauma to large masses of tissues consists in the main of blood plasma. Undoubtedly some fluid passes from the uninjured tissue spaces into the blood stream, but fluid continues to be lost at the site of injury and an increase in the concentration of the red blood cells in the vessels results.

As a result of these and other observations, it seems that the local loss of fluid at the site of injury is responsible for the shock that develops following injury to large masses of muscle. It is not maintained that all or the majority of instances of shock are due to this cause. For example, the declines in blood pressure which sometimes follow intra-abdominal operations, injury to the brain, and the perforation of ulcers are probably brought about by different mechanisms.

It is to be emphasized that there are contributory factors that frequently play a part in the production and maintenance of shock. Food and water deprivation increase the susceptibility to shock. Exposure to cold increases the ease with which it can be produced. Just as a serious illness reduces one's ability to withstand the loss of blood, similarly it lessens the amount of trauma that can be tolerated. Profuse sweating following injury reduces the volume of fluid available for the blood stream. I have observed recently (10) that the prolonged anæsthetization of normal dogs by ether causes capillary congestion and hæmorrhage in many of the organs of the body. It frequently results in the escape of blood into the lumen of the intestinal tract. These alterations diminish somewhat the loss of fluid that can be tolerated.

### PREVENTION AND TREATMENT OF SHOCK

As regards the prevention of shock, only several of the more important points will be mentioned. The maintenance of the body temperature at as nearly the normal level as possible is exceedingly important in patients who have been injured and in those upon whom operations are performed. The patient who has been severely injured should if possible be wrapped in blankets before being transported. If the clothing is wet, it should be removed as soon as dry clothing is available. Patients who are to be operated upon should not receive drastic purgatives. This is especially important if it is necessary to restrict the intake of fluids following the operation. If a person receives a fracture of a long bone, and particularly if it is the femur, the part should be splinted before the patient is moved. In cases of severe injury in which the diagnosis has been made and in which damage to the brain is not suspected, morphine should be given. In the presence of gross injury to an extremity, the application of a tourniquet is usually the quickest method of stopping hæmorrhage. However, it is very important that the tourniquet should not be left in place for a considerable time if an attempt is to be made to save the part. In the presence of a low or declining blood pressure, local or gas-oxygen anæsthesia is preferable to ether or chloroform or spinal. It should be remembered that a person may have lost a great deal of blood and still have an essentially normal blood pressure, but yet the loss of a slight additional quantity may result in severe shock. Rigid hæmostasis and the gentle handling of tissues become even more imperative than usual under these circumstances. If the blood volume has been diminished by hæmorrhage, transfusion should be performed if possible before any operative procedure is carried out.

The principles that have been mentioned apply also to the treatment of shock. The two methods that are used most commonly in an attempt to better the condition of the patient are the giving of vasoconstrictor drugs

and the introduction of various fluids. The giving of drugs which produce vasoconstriction causes a rise in blood pressure but it is seldom sustained except in primary shock. It is important to realize that the aim in treating secondary shock is not to produce a high blood pressure but to cause an increase in the volume of the circulating blood. This is seldom accomplished by the use of drugs. When vasoconstriction is produced, the amount of blood reaching the organs may be decreased rather than increased. The ideal method of treating the condition would be to introduce into the blood stream some fluid that would remain there, thus increasing both the volume of blood and the blood pressure. Unfortunately, not even blood will meet these requirements when the state of shock has existed for a considerable time.

In association with Drs. Beard, Wilson, and Weinstein (2), the effects on the blood volume and on the protein content of the blood plasma of introducing the various fluids that are commonly used in treating shock was studied. Special attention was devoted to the protein content of the plasma because it is the substance that attracts fluid into the blood stream and holds it there and this is what one wishes to accomplish in the treatment. The remarks here will be limited to the effects of the intravenous introduction of fluids into animals in which gross injury to capillaries had been produced. They apply to all conditions, including that produced by hæmorrhage, resulting from a markedly depressed blood pressure of several hours' duration. The intravenous injection of solutions of crystalloids such as salt or glucose under these circumstances was associated with not only the loss of the greater part of the fluid that was injected, but also with a decrease in the protein content of the plasma remaining in the vessels. When whole blood or blood serum was introduced intravenously under similar conditions, plasma and hence proteins were lost through the capillary walls, but a decrease in the protein content of the plasma remaining in the vessels did not occur since protein was present in the blood that was injected. The addition of adrenalin or pituitrin (14) to the various fluids that were injected into the blood stream did not seem to lessen the loss of plasma.

## A CLASSIFICATION OF ACUTE CIRCULATORY FAILURE FROM A PHYSIOLOGICAL VIEWPOINT

If the term shock is to be retained in medical literature, it is important that its meaning should be clearly defined. The word should be used in a generic sense to include a clinical syndrome which is familiar to all. The most striking features of the fully developed condition are apathy, pallor, sweating, cold extremities, thirst, a weak pulse, and vomiting.

The work of recent years has shown that this clinical picture is dependent on an inadequate blood supply to the tissues of the body. This may be brought about in several ways and since treatment depends primarily on the underlying disturbance, it is important that we classify the different types of acute circulatory failure from the physiological viewpoint.

*1. Hæmatogenic type.* First to be considered is the hæmatogenic type. The initial and the most important circulatory change is the diminution in the blood volume. Unless the initial decrease in blood volume is too great, compensatory vasoconstriction maintains the arterial blood pressure at or near the normal level. The decline in blood volume is followed by a decrease in the return of blood to the heart and hence in a decrease in the cardiac output. If the volume of circulating blood continues to diminish, the blood pressure declines even though vasoconstriction is maintained. If the blood pressure remains depressed for a considerable time, the vasoconstrictor mechanism fails and vasodilatation results. When this stage has been reached, many other factors enter into the picture and make the condition worse. Most of these factors are probably common to all types of severe shock regardless of the mechanism of the production. These include an insufficient supply of oxygen to the tissues with resulting damage, a decrease in the production of heat, an increase in the viscosity of the blood, an increase in capillary permeability, a diminution in the alkali reserve and probably the accumulation of toxic products. The important alterations are the early

ones. It is concerning the cause for the decline in blood pressure that most of the theories have been advanced.

It is with the hæmatogenic type of shock that this paper is largely concerned. Shock as a result of uncomplicated hæmorrhage is the simplest example. Shock following trauma to large masses of muscle belongs to this group if my experiments and those of Parsons and Phemister have been interpreted correctly. If the characteristics of this type are an initial decline in the blood volume, vasoconstriction, a decrease in the output of the heart before the blood pressure alters appreciably and the local loss of enough of the blood volume to account for ultimate decline in pressure, then they are all met by the experiments in which the extremities were injured. The fact that the simple removal of blood in such manner that the blood pressure will remain at a low level for as long as possible, may be associated with an increase in the concentration of the blood, a negative response to transfusion and capillary congestion and hæmorrhage in the tissues, lends support to this belief.

2. *Neurogenic type.* This term is used to designate the condition that is usually known as primary shock or collapse. It is more rapid onset than the hæmatogenic type. A satisfactory explanation for the conditions seems to have been offered by Goltz. The primary alteration is vasodilatation dependent on diminished constrictor tone as a result of influences acting through the nervous system. The major circulatory disturbance at first consists of a decline in blood pressure, but if it remains depressed, the volume of blood and the output of the heart decrease. Neurogenic shock may be brought about by agencies which influence the nervous system directly, such as spinal anæsthesia or trauma, or it may be reflex in origin as for example the collapse that follows a severe blow on the abdomen.

3. *Vasogenic type.* Vascular dilatation may be brought about by agencies which act directly on the vessels. Histamine probably exerts the major portion of its effect in this manner. It has been shown that the administration of histamine is associated with a primary fall in the blood pressure and that the output of the heart declines later. The shock that follows the removal of the adrenal glands probably belongs to this type.

4. *Cardiogenic type.* Acute circulatory failure as a result of primary disturbance of the heart occurs very rarely. It is characterized by venous distention in contrast to the collapsed condition of veins that is found in peripheral circulatory failure. A rapid accumulation of fluid in the pericardial cavity produces this type of alteration. Shock associated with deep anæsthesia by chloroform probably belongs in the main to this type.

5. *Unclassified conditions.* Many different factors may enter into the production of shock that is associated with operations. Among these may be included, hæmorrhage, loss of plasma from the exposed surfaces, loss of water from the body by sweating or possibly preliminary purging, dilatation of vessels as a result of mechanical irritation and vascular reflexes, infection, anæsthesia, and particularly the disease for which the operation is performed. The simple opening of the peritoneal cavity is frequently associated with a temporary decline in the blood pressure which is probably reflex in origin. The circulatory collapse that occurs following the rupture of a hollow viscus such as a perforation of a duodenal ulcer appears, because of its sudden onset, to be, at least partially, reflex in origin. Probably many different factors enter into the production of the circulatory failure that frequently results from peritonitis. These include the loss of large amounts of fluid from the blood stream into the peritoneal cavity, the dilatation of the blood vessels as a result of the presence of irritating substances, the various actions of the toxic products of the infection and the effects of the disease that caused the peritonitis. The mechanism of the circulatory failure that occurs in pneumonia, typhoid fever, and other severe infections is probably equally complicated.

Such are the various types of acute circulatory failure. They may be produced by the most diverse diseases and may be dependent on several different fundamental physiological disturbances. The eventual result is the appearance of a clinical picture which may be designated as shock.

In conclusion, it is probably unnecessary to state that our information concerning many types of acute circulatory failure is still incomplete. However, some definite advances have been made since Travers presented his contributions more than one hundred years ago. At least, shock has been stripped of much of the mystery that surrounded it. I have not intended in any manner to belittle the views of those who have preceded us, for their contributions form an integral part of our present conception of the condition. Although there is at present no satisfactory treatment for shock which has persisted for several hours, a better understanding of the underlying causes has led to a great diminution in the incidence of shock and to the more successful treatment of the condition during the early stages of its development.

## BIBLIOGRAPHY


1. Beard and Blalock. Experimental shock. The composition of the fluid that escapes from the blood stream after mild trauma to an extremity, after trauma to the intestines and after burns. Arch. Surg., 1931, xxii, 617.
2. Beard et al. J. Clin. Invest., 1932, xii, 249, 267, 291, 311.
3. Bichat. Physiological Researches upon Life and Death. Translated by Tobias Watkins. Philadelphia: Smith and Maxwell, 1809.
4. Billroth, T. Handbuch der allegemeinen und speciellen Chirurgie von Pitha und Billroth. Quoted by Groeningen. Erlangen, 1867.
5. Blalock, Alfred. Mechanism and treatment of experimental shock. Shock following hæmorrhage. Arch. Surg., 1927, xv, 762.
6. Idem. Experimental shock. The cause of the low blood pressure produced by muscle injury. Arch. Surg., 1930, xx, 959.
7. Idem. Trauma to the intestines. The importance of the local loss of fluid in the production of the low blood pressure. Arch. Surg., 1931, xxii, 314.
8. Idem. Experimental shock. The probable cause for the reduction in blood pressure following mild trauma to an extremity. Arch. Surg., 1931, xxii, 598.
9. Idem. Experimental shock. The importance of the local loss of fluid in the production of the low blood pressure after burns. Arch. Surg., 1931, xxii, 610.
10. Idem. Unreported observations, 1933.
11. Blalock and Beard. The effects of adrenalectomy on the cardiac output and blood pressure. J. Lab. & Clin. Med., 1933, xviii, 941.
12. Blalock and Bradburn. Trauma to the central nervous system. Its effects on cardiac output and blood pressure. An experimental study. Arch. Surg., 1929, xix, 725.
13. Idem. Distribution of the blood in shock. The oxygen content of the venous blood from different localities in shock produced by hæmorrhage, by histamine and by trauma. Arch. Surg., 1930, xx, 26.
14. Blalock, Wilson, Weinstein, and Beard. Loss of protein from the blood stream. Effects of the injection of solution of pituitary and of epinephrine. Arch. Surg., 1933, xxvi, 330.
15. Blum, Albert. Du Shock Tramatique. Arch. gén. d. méd., Par., 1876, January.
16. Boise, Eugene. The nature of shock. Am. J. Obst., 1907, lv, 1.
17. Buck, Albert H. The Dawn of Modern Medicine. Yale University Press. New Haven, 1920.
18. Burch and Harrison. The effect of spinal anæsthesia on the cardiac output. Arch. Surg., 1930, xxi, 330.
19. Idem. The effect of spinal anæsthesia on arterial tone. Arch. Surg., 1931, xxii, 1040.
20. Cannon, W. B. Traumatic Shock. New York: D. Appleton and Co., 1923.
21. Ibid. P. 135.
22. Cannon and Bayliss. Note on muscle injury in relation to shock. Rep. Med. Research Council, 1919, March, No. 26, 19–23.
23. Clark, F. Le Gros. Lectures on the principles of surgical diagnosis especially in relation to shock and visceral lesions. London: John Churchill and Sons, 1870.
24. Crile, G. W. An Experimental Research into Surgical Shock. Philadelphia: J. B. Lippincott Co., 1897; Blood Pressure in Surgery. Philadelphia, 1903; Hæmorrhage and Transfusion. New York and London: D. Appleton and Co., 1903; Anoci-Association (with W. E. Lower). Philadelphia: W. B. Saunders, 1915.
25. Idem. A Bipolar Theory of Living Processes. New York: The MacMillan Company, 1926.
26. Daniel, Upchurch, and Blalock. The absorption from traumatized muscles. Surg., Gynec. & Obst., 1933, li, 1017.
27. Dawson, W. R. Magician and Leech. London: Methuen and Co., Ltd., 1929.
28. Dolley, David H. The cytological analysis of shock. J. Med. Research, 1916, xxix, 305.
29. Erlanger, J., Gesell, R., and Gasser, H. S. Studies in secondary traumatic shock. I. The circulation in shock after abdominal injuries. Am. J. Physiol., 1919, xlix, 90.
30. Erlanger et al. Am. J. Physiol., 1919, xlix, 90, 151, 345; l, 31, 104, 119.
31. Erlanger, J., and Gasser, H. S. Studies in secondary traumatic shock. III. Circulatory failure due to adrenalin. Am. J. Physiol., 1919, xlix, 345.
32. Fischer, H. Ueber den Shok. Samml. klin. Vortr., 1870, No. 10.
33. Forbes, A., and Miller, R. H. Detection with the string galvanometer of afferent impulses in the brain-stem and their abolition with ether anæsthesia. Am. J. Physiol., 1916, xl, 148.
34. Idem. The effect of ether anæsthesia on afferent paths in the decerebrate animal. Am. J. Physiol., 1922, lxii, 113.
35. Freedlander and Lenhardt. Traumatic shock. Arch Surg., 1932, xxv, 693.
36. Freeman, N. E. Cortin and traumatic shock. Science, 1933, lxxvii, 211.
37. Idem. Decrease in blood volume after prolonged hyper-activity of the sympathetic nervous system. Am. J. Physiol., 1933, ciii, 185.
38. Garrison, F. H. An Introduction to the History of Medicine. Philadelphia: W. B. Saunders Company, 1924.
39. Goltz, Fr., Vagus, and Herz. Arch. f. path. Anat. u. Physiol., 1863, xxvi, 1.

40. GOLTZ, FR. Ueber den Tonus der Gerfæsse und seine Bedeutung fuer die Blutbewegung. Arch. f. path. Anat. u. physiol., 1864, xxix, 394.
41. GROENINGEN, G. H. Ueber den Shock. Wiesbaden: J. F. Bergmann, 1885.
42. GROSS, SAMUEL D. System of Surgery. Pathological, Diagnostic, Therapeutic and Operative. 5th ed. Philadelphia: Henry C. Lea, 1872.
43. HENDERSON, YANDELL. Acapnia and shock. I. Carbon-dioxide as a factor in the regulation of the heart rate. Am. J. Physiol., 1908, xxi, 126.
44. HIPPOCRATES. Quoted by Ambroise Paré. Les Oeuvres. 12th ed., p. 208. Lyon: Jean Gregoire, rue Merciere, 1664.
45. Idem. P. 214.
46. HOWELL, W. H. Contributions to medical research. Dedicated to Victor Vaughn, 1903.
47. HUNTER, JOHN. The Complete Works of. Vol. iii. Edited by JAMES F. PALMER. Philadelphia: Haswell, Barrington & Haswell, 1841.
48. JOHNSON and BLALOCK. Experimental shock. A study of the effects of the loss of whole blood, of blood plasma and of red blood cells. Arch. Surg., 1931, xxii, 626.
49. JOHNSON and BLALOCK. Experimental shock. A study of the effects of hemorrhage, of trauma to muscles, of trauma to the intestines, of burns and of histamine on the cardiac output and blood pressure of dogs. Arch. Surg., 1931, xxiii, 855.
50. JORDAN, FURNEAUX. Surgical Enquiries. London: J. and A. Churchill, 1880.
51. Journal of American Medical Association, 1933, c, 46.
52. KEITH, N. M. Blood volume changes in wound shock and primary hemorrhage. Rep. Med. Research Council, 1919, No. 27, March.
53. KOCHER, R. A. The effect of activity on the histologic activity of nerve cells. J. Am. M. Ass., 1916, lxvii, 279.
54. LARREY. Memoirs of Military Surgery. Translated by R. W. Hall. Baltimore: John Cushing, 1814.
55. MALCOLM, JOHN D. On the condition of the blood vessels during shock. Lancet, 1907, i, 497.
56. MANN, F. C. Shock during general anæsthesia. J. Am. M. Ass., 1917, lxix, 371.
57. MANN, H. C. The peripheral origin of surgical shock. Bull. Johns Hopkins Hosp., 1914, xxv, 205.
58. MANSELL-MOULLIN, C. W. Shock. The International Encyclopedia of Surgery. Edited by J. Ashurst. Vol. i, p. 357. London, 1882.
59. MAPOTHER, E. D. Shock: its nature, duration and mode of treatment. (Transactions of Surgical Society of Ireland.) Brit. M. J., 1879, ii, 1023.
60. Memorandum upon surgical shock and some allied conditions, issued by the Medical Research Committee. Brit. M. J., 1917, i, 381.
61. MELTZER, S. J. The nature of shock. Arch. Int. Med., 1908, i, 587.
62. MITCHELL, S. WEIR. Injuries of Nerves and Their Consequences. Philadelphia: J. B. Lippincott Co., 1872.
63. PARSONS and PHEMISTER. Hæmorrhage and shock in traumatized limbs. An experimental study. Surg., Gynec. & Obst., 1930, li, 196.
64. PHEMISTER and HANDY. Vascular properties of traumatized and laked bloods. J. Physiol., 1927, lxiv, 155.
65. PORTER, W. T. The effect of uniform afferent impulses upon the blood pressure at different levels. Am. J. Physiol., 1907, xx, 399.
66. Idem. Fat embolism shock is not explained by embolism of the lungs. Boston M. & S. J., 1919, clxxx, 531.
67. PORTER, W. T., MARKS, H. K., and SWIFT, J. B. The relation of afferent impulses to fatigue of the vasomotor centre. Am. J. Physiol., 1907, xx, 444.
68. PORTER, W. T., and QUINBY, W. C. Further data regarding the condition of the vasomotor neurones in shock. Am. J. Physiol., 1908, xx, 500.
69. QUÉNU. Rev. de chir., 1918, lvi, 204.
70. Report of the Medical Research Council, 1919, No. 25, 250.
71. ROOME, KEITH, and PHEMISTER. Experimental shock: the effect of bleeding after reduction of the blood pressure by various methods. Surg., Gynec. & Obst., 1933, lvi, 161.
72. SAVORY, W. S. Collapse; and the General Effects of Shock Upon the System. Holmes System of Surgery. Philadelphia: Henry C. Lea's Son and Co., 1881.
73. SEABROOK, C. C. The pathology of shock. Tr. Med. Soc. Pennsylvania, 1881, p. 653.
74. SEELIG, M. G., and LYON, E. P. The condition of the peripheral blood vessels in shock. J. Am. M. Ass., 1909, lii, 45.
75. SMITH, M. I. Studies on experimental shock with especial reference to its treatment. J. Pharmacol. & Exper. Therap., 1928, xxxii, 465.
76. SPENCER, W. B., and GILLEN, F. J. The native tribes of Central Australia. London, 1899.
77. STARLING, E. H. Arch. méd. belges, 1918, lxxi, 369.
78. SWINGLE, W. W., PFIFFNER, J. J., VARS, H. M., BOTT, P. A., and PARKINS, W. M. The function of the adrenal cortical hormone and the cause of death from adrenal insufficiency. Science, 1933, lxxvii.
79. TRAVERS, BENJAMIN. An Inquiry Concerning that Disturbed State of the Vital Functions Usually Denominated Constitutional Irritation. New York: H. Stevenson, 1826.
80. TULLY. Quoted by O. W. Holmes. Medical Essays. Boston: Houghton, Mifflin and Co., 1883.
81. TYRELL, FREDERICK. The lectures of Sir Astley Cooper on the Principles and Practice of Surgery. Philadelphia: Haswell, Barrington & Haswell, 1839.
82. UNDERHILL, KAPSINOW, and FISK. Studies in the mechanism of water exchange in the animal organism. II. Changes in capillary permeability induced by a superficial burn. Am. J. Physiol., 1930, xcv, 315.
83. WARTHIN, A. S. Traumatic lipaemia and fatty embolism. Internat. Clin., 1913, iv, Series 23, 171.
84. WARREN, JOHN COLLINS. Surgery, Pathology and Therapeutics. Philadelphia: W. B. Saunders Co. 1900.

# OXYGEN PNEUMOPERITONEUM IN THE DIAGNOSIS AND TREATMENT OF TUBERCULOSIS OF THE GENITALIA, INTESTINE AND PERITONEUM[1]

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IT is, indeed, fitting that here in Chicago during the celebration of A Century of Progress this Congress of Physical Therapy shall record another step forward in the diagnosis and treatment of intra-abdominal tuberculosis. The surgical treatment, which up to the present time had become the method of choice in the care of tuberculous peritonitis, was discovered by mistake, and at the same time, the use of oxygen therapy in the treatment of this condition was born. In 1872, Spencer Wells operated upon a woman for ovarian cyst but when the abdomen was opened he found instead tuberculosis of the peritoneum. In this instance cure followed the mere opening and closing of the abdomen. Wells, however, did not appreciate the significance of this result, and it was not until 1884 when Koenig advocated the surgical treatment of tuberculous peritonitis that it became a recognized procedure. The interpretation of the *modus operandi* has led in many directions; as Hertzler says, the fact that there are about twenty theories advanced to explain how simple laparotomy cures tuberculous peritonitis is in itself enough to throw doubt upon the value of operation.

Lauenstein believed that the cure by laparotomy resulted from the removal of fluid and the action of light during the short exposure at operation, and Joseph Price named it the "sunshine operation." This action is definitely disproved by the puncture method, various gases having been successfully used to insufflate the abdomen. Nolen used sterilized air and obtained cure. Filtered air, atmospheric air, nitrogen, and finally oxygen were successively used therapeutically. Maestrini (1925) claims to be the originator of the oxygen method, although there are a number of references to its adoption earlier (McGlinn, A. Stein, Bainbridge). He analyzed the results of air inflation, tried nitrogen without success (although Santorsola prefers nitrogen as he believes it is less rapidly absorbed), and finally introduced pure oxygen. He claims that oxygen has a specific action on the tubercle bacillus and on its enzymes. In his animal experiments he found that the speed of absorption of oxygen in the peritoneal cavity of rabbits gradually diminished with successive insufflations. The peritoneum after contact with oxygen does not allow organic colloids to pass through, but it has a greater than the normal permeability to crystalloids. Furthermore, ascitic fluid in contact with oxygen becomes less alkaline and has increasing oxydizing action. The method of air insufflation was initiated by von Mosetig-Moorhof in 1892; the curative action of the injected air, however, was first attributed by Floris to its oxygen content. Bainbridge believes that oxygen acts as a germicide. Silvestri, in 1911, concluded as follows: (1) the introduction of atmospheric air into the pleural and peritoneal cavities is the most efficacious method of treatment for tuberculous serositis; (2) the quantity of air insufflated should correspond to that of the fluid removed; (3) atmospheric air not only does not cause any inconvenience, not only does not contaminate the serous cavity, but is shown to be far more effective than filtered or sterilized air; (4) this method is indicated in tuberculosis of any serous surface, wherever found.

Norris disagrees that the admittance of air into the abdomen is the reason for cure of patients operated upon, but believes that the removal of fluid is the chief beneficial agent. It is commonly known, however, that fluid increases rapidly after tapping unless air or oxygen is insufflated, and furthermore, how does Norris explain the cures of patients operated upon or insufflated by puncture in whom there was no demonstrable fluid?

[1]Read before the American Congress of Physical Therapy, September 11 to 16, 1933.

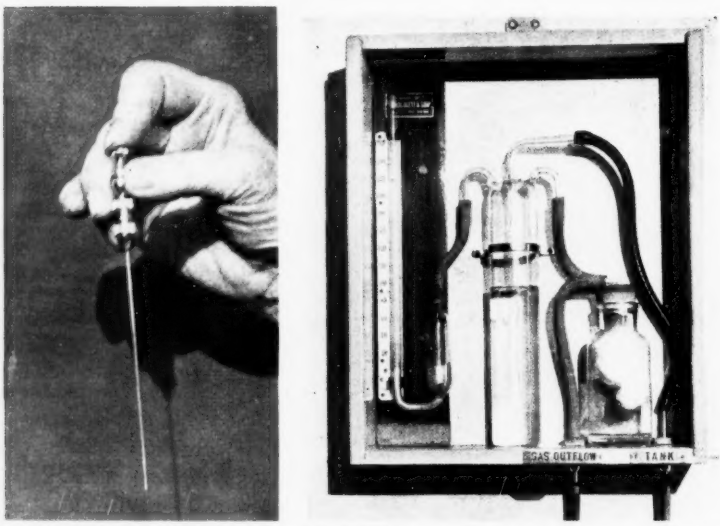


Fig. 1. Needle used for transabdominal pneumoperitoneum and insufflation apparatus.

Norris apparently ignored the literature on oxyperitoneum when revising his monograph (1931), while Hertzler's valuable book on *The Peritoneum* published 9 years earlier quotes McGlinn as using oxygen insufflations for tuberculous peritonitis in 1908. In his chapter on genital tuberculosis in Curtis' *Obstetrics and Gynecology*, 1933, Norris says, "In some instances the careful injection of oxygen into the peritoneal cavity may prove of value." There are numerous other contributions in the medical literature on oxygen therapy in tuberculous peritonitis between 1925 and the present time.

If the value of laparotomy lies in the exposure of the tissues to oxygen, then it is quite logical that the simple introduction of pure oxygen or air should replace the surgical exploration. Puncture is simply and safely done, and inflation of the abdomen with anywhere from 100 to 1000 cubic centimeters of gas requires at most 24 to 48 hours' hospitalization. In addition to sparing the patient the pain and danger of laparotomy, there is a great economic gain in utilizing the puncture method. Furthermore, the genital structures may be conserved in tuberculous salpingitis; much is to be gained and nothing lost by giving the more conservative method a trial. If no beneficial effects are noted in 10 to 14 days, the injection may be repeated, and if no improvement occurs, laparotomy may still be performed, the gas having done no harm.

## DIAGNOSTIC PNEUMOPERITONEUM IN GENITAL TUBERCULOSIS

It is commonly acknowledged that the diagnosis of tuberculous salpingitis—the commonest cause of tuberculous peritonitis—is difficult to establish. Occurring in from 5 to 10 per cent of inflammatory lesions of the fallopian tubes, and a common cause of salpingitis in the virgin, it frequently escapes recognition until exploration of the abdomen and pelvis is made. It may be suspected, however, after a careful study of the patient's history and the proper evaluation of abdominal and bimanual examination. Laboratory aids are usually required in addition to establish the correct diagnosis.

As in the case of obscure pelvic conditions in the general run of gynecological materia, so also in pelvic tuberculosis the employment of diagnostic pneumoperitoneum is of decided value in arriving at a correct diagnosis without recourse to laparotomy. We have pre-

Fig. 2. Pneumograph after pneumoperitoneum. The roentgenogram reveals normal uterus, ovaries, and tubes.

Fig. 3. Author's combined method of pneumoperitoneum, and uterosalpingography. Hypoplastic uterus; normal ovaries and patent tubes.

viously stated (23, 24) that in our service we have practically eliminated the resort to exploratory laparotomy in our pelvic surgery since utilizing diagnostic pneumoperitoneum, and we have employed the method in well over one thousand cases within the past 10 years.

In suspected pelvic tuberculosis, oxygen is used in place of carbon dioxide because of its therapeutic as well as its diagnostic value in this condition. When tuberculosis is present, often involving the pelvic structures, peritoneum, and intestines, repeated oxygen insufflations are used. We have encountered no serious accidents in performing transabdominal puncture and believe that if the same degree of caution is exercised as in the puncture of other body cavities, i.e., pleura, spinal canal, the objections cited by those who fear to use it may be easily overcome. By means of diagnostic pneumoperitoneum, alterations in the size, shape, density, and relationship of the various pelvic organs, and especially the presence or absence of adhesions may be demonstrated clearly in the X-ray film. Numerous contributors besides ourselves have attested to this observation. After one has gained an experience in interpreting the normal pneumographic findings in pelvic roentgenography, pathological conditions are more or less readily recognized with a high degree of accuracy.

It is usually sufficient to insufflate the abdomen with a liter of oxygen to demonstrate the presence of pelvic tuberculosis; iodized oil may also be employed in combination with oxygen insufflation when it is desirous to demonstrate the relationship of the uterine cavity and fallopian tubes in a large pelvic mass (as in author's Case 1). The combined method has previously been discussed by us (24). The fallopian tubes in tuberculosis are usually greatly enlarged, tortuous, and thickened so that they cast an unusually dense shadow on the roentgen film, and they are usually patent. Sometimes calcium deposits in the tube wall are demonstrable. Dense intestinal adhesions are commonly found particularly in the plastic variety, which are readily recognized on the film. A moderate amount of serous exudate is no contra-indication; if large amounts are present, tapping should precede the introduction of oxygen. As to the range of the use of oxygen insufflations in various types of intra-abdominal tuberculosis, the following briefly stated case histories will best serve as illustrations.

Fig. 4.

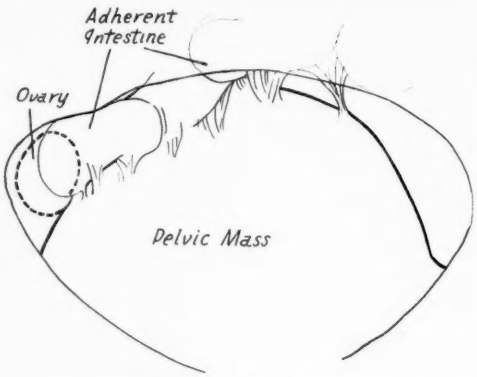


Fig. 4. Pelvic tuberculosis. Oxygen pneumoperitoneum. Large pelvic mass with intestinal adhesions. (Author's Case 1.)

TECHNIQUE

The procedure is exceedingly simple and differs in no way from that of the transabdominal pneumoperitoneum with carbon dioxide used for gynecological diagnosis (25). It is advisable that about an hour before treatment the bowels be emptied by means of a cleansing enema. One-half hour before, morphine sulphate (alone or combined with scopolamine hydrobromide) should be administered, the dose depending upon the age, condition, and size of the patient. For the average adult who is in fairly good condition, ¼ grain of morphine may be used, combined with 1/150 grain of scopolamine. The bladder should be empty just before treatment. The skin of the lower abdomen is prepared with alcohol followed by 2 per cent mercurochrome solution which is allowed to dry. A rather firm, inflexible needle of 3 inches in length and fitted with a stylette is introduced through the abdominal wall, no local anæsthetic being required. The point of introduction is usually one inch to the left of the umbilicus and slightly below that level. The needle is held vertically, between the thumb and third finger, at right angles to the skin, and is introduced into the peritoneal cavity by means of pressure of the forefinger on the stylette. Three resistances are met; first, the skin, second, the aponeurosis, and third, the more sensitive peritoneum. After a brief experience one can readily tell whether or not the needle has entered the peritoneal cavity from the sensation experienced when a cavity is punctured. The unimpeded flow of the gas, evidenced by a low stationary manometric reading, gives assurance of intraperitoneal entry. The needle is attached to the oxygen insufflation apparatus by means of rubber tubing and an adaptor. The apparatus ordinarily used for Rubin patency test (Fig. 1) of the fallopian tubes is fully adequate, an oxygen tank supplanting that of carbon dioxide. If fluid is present, about a liter may be removed by trochar, and the latter used for insufflation, from one-half to the same amount of oxygen being introduced as that of fluid evacuated. A liter of oxygen produces little discomfort from distention and is usually a sufficient dose. The needle is quickly withdrawn and with needle puncture no dressing is required. The patient is kept flat on the X-ray table, the same position being maintained during transportation back to bed, to prevent "shoulder pain" from gas entering the right subdiaphragmatic space. (The procedure can also be carried out at the bedside.) Shoulder pain may be relieved by elevating the patient's hips with a pillow or by raising the foot of the bed for a few hours. Within 48 hours all signs of oxygen have usually disappeared and probably repeated injection

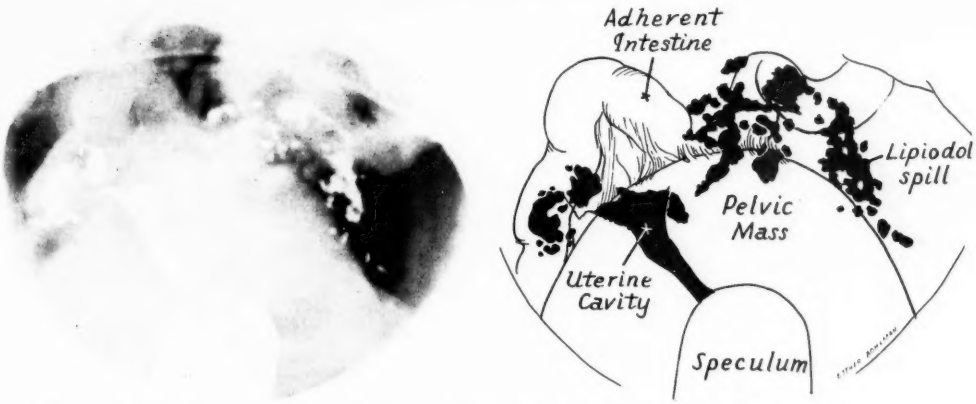


Fig. 5. Combined oxygen pneumoperitoneum and uterosalpingography (Case 1) 9 days after first injection.

could safely be made at this time. Those who have used the method have repeated insufflation in from 4 days to 2 weeks. We recommend weekly insufflations of about one liter each, the number of doses depending upon the results obtained. It is our practice to keep all patients in bed 18 to 24 hours after every pneumoperitoneum treatment whether diagnostic or therapeutic.

Early in the treatment of tuberculosis of the peritoneum, the patient is usually hospitalized and in bed. When improvement sets in and temperature is normal, 48 hours' bed rest after each treatment should suffice.

## INDICATIONS

Therapeutic oxyperitoneum is applicable to children and adults alike, and although most of the work has been done on women, its use should be extended to men with tuberculous peritonitis. The patient should be in fairly good physical condition; moribund patients are not suitable for this method. There is some question whether introduction of the needle can be safely made in the plastic form of tuberculosis; in grave pulmonary tuberculosis, and advanced, ulcerative intestinal tuberculosis, the method is contraindicated. It is usually advisable to wait until acute symptoms have subsided and the temperature is low before starting oxygen insufflation as a febrile reaction for a day or two has been observed by some physicians who have employed this method of treatment. In our cases this did not occur. Pregnancy is regarded by Lucherini as a contra-indication to insufflation. During the first 3 months of pregnancy, however, when the uterus is not likely to be traumatized by puncture there is no harm in small, repeated oxygen insufflations. It may be emphasized here that pregnancy favors the development of tuberculous peritonitis. Kelly found 28 per cent of his series of pelvic tuberculosis dating from childbirth.

## CASE REPORTS

It is not the purpose of this paper to cite all the case reports in the world's literature on oxygen therapy in pelvic tuberculosis; a sufficient number will be abstracted, however, to exemplify the beneficial effects of this method.

*Curti* uses Kuesse's apparatus for oxygen insufflation and injects slowly. He controls arterial tension and the cardiac condition. He introduces half as much gas as liquid evacuated in the exudative variety. A few insufflations are considered enough. He recommends the additional use of 10 to 12 grains of calcium chloride daily to prevent reappearance of fluid.

A boy, aged 17 years, previously healthy, took ill with influenza. He had fever and a dry cough for 2 months, and as improvement set in, hardness and swelling of the abdomen were noted. Tuberculous peritonitis was diagnosed. Climatic therapy and dietetic measures failed. Laparotomy was done, and while healing was uncomplicated, fever and abdominal swelling continued. There was also a hydro-thorax. Hæmoglobin was 52 per cent, and the red blood count was 3,347,000. After the removal

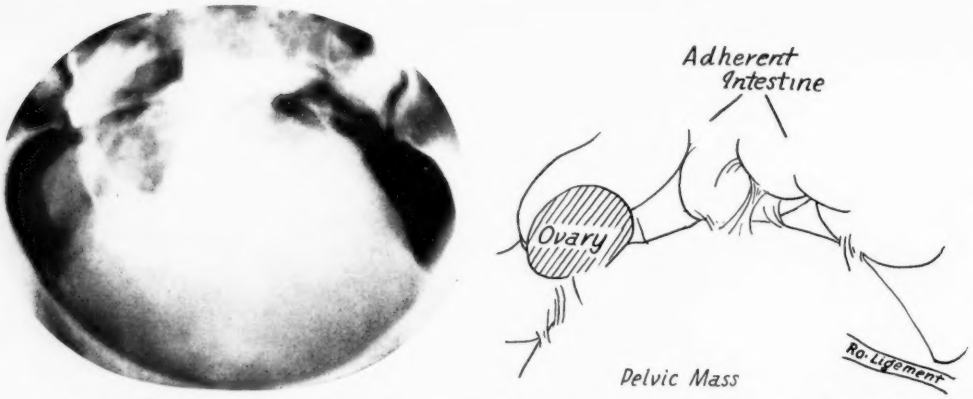


Fig. 6. Oxygen pneumoperitoneum 1 month after treatment. Patient fever free, gained 12 pounds. (Case 1.)

of 3 liters of fluid from the abdomen, 1500 cubic centimeters of oxygen was introduced. Calcium chloride was given by mouth. Ten days later a second insufflation was done. In another 10 days, the patient's condition was excellent; the fever, pleural and peritoneal effusion had disappeared. Abdominal masses could still be palpated. The hæmoglobin rose to 70 per cent and the red blood count to 4,100,000. Five days later, the patient was in good condition, chest was normal, weight had increased 2 kilograms, and the abdomen was normal except for some rather hard spots in the upper portion.

*Lucherini* used a simple insufflation of atmospheric air, the amount equalling about half that of the fluid removed. He reports 18 cases, of which the following are typical:

Case 1. A man, aged 21 years, showed symptoms for 1 month. He had a moderate fever. Clear, yellow fluid, the amount being about 2400 cubic centimeters, was removed and 1100 cubic centimeters of air was introduced. A rapid improvement was shown. He left the hospital in a little over a month in good general condition after a single air insufflation with no sign of free fluid.

Case 2. A girl, aged 14 years, had 2½ liters of hæmorrhagic fluid removed and 1200 cubic centimeters of air introduced. Five days later there were no signs of free fluid in the abdomen. The patient left the hospital 1 month after the single air insufflation in excellent condition.

Case 3. A woman, aged 36 years, showed symptoms for 2 months. Two thousand six hundred cubic centimeters of fluid was removed, and 1300 cubic centimeters of air was insufflated. She left the hospital in 1 month in excellent condition with no sign of peritoneal disease.

In Case 17, the author repeated the injection of air after 1 month as the effusion did not disappear following the first. After a second air injection, however, the patient completely recovered.

*Maestrini* treated 4 patients with tuberculous ascites with complete recovery after three or four oxygen insufflations. He drew off a quantity of ascitic fluid and insufflated 150 to 200 cubic centimeters of oxygen. A fifth case under treatment at the time of his report was in the process of recovery after 2 instillations of oxygen. He studied the speed of absorption of the gas by noting the change in the circumference of the abdomen, taking into account the gradual reaccumulation of fluid. He found that in exudative tuberculous peritonitis, the speed of absorption of oxygen diminished with successive insufflations; at the same time the fluid collected more and more slowly, showing a direct relationship between the two processes. This relationship was totally absent in a case of ascites from stasis (not tuberculous). The following year (1926), Maestrini reported 3 additional cases, two of which were permanently and one temporarily cured by oxygen insufflation.

*Santorsola* reports a case of a man 20 years of age who was not benefited by laparotomy, but became rapidly worse and fluid increased greatly. Santorsola insufflated 600 cubic centimeters of nitrogen after removing 2 liters of fluid. After 13 days, there was some relief and the treatment was repeated, 4 liters of fluid being removed and 1500 cubic centimeters of nitrogen introduced. Two months after the first insufflation the abdomen appeared normal and the general condition of the patient was greatly improved. Four months later, he was in excellent condition. Santorsola believes that the mode of action of the gas is the distention and isolating of peritoneal leaves preventing friction and putting the serosa at rest. The gas also favors fibrous transformation of the tubercle. He prefers nitrogen because he says it is less rapidly absorbed. Maestrini, on the other hand, failed to get results with nitrogen.

*A. Stein (22), of New York.* Case 1. A woman, aged 32 years was operated upon for retroversion. Three months later, there was an exudative tuber-

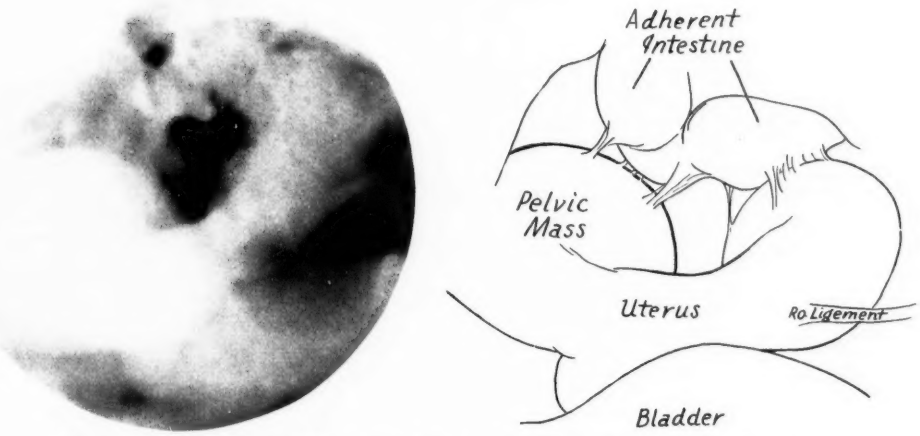


Fig. 7. Oxygen pneumoperitoneum 4 months after treatment, gained 19 pounds. (Case 1.)

culous peritonitis. Four oxygen insufflations of 4 liters each, 3 to 5 days apart, were given. Recovery followed. (The patient was operated upon for an ovarian malignancy some years later, the sections revealing Bacillus tuberculosis.)

Case 2. A child, 11 years old, had exudative tuberculous peritonitis. Ten oxygen insufflations were given after the removal of fluid; there was a marked improvement.

Stein uses far greater quantities of oxygen (sometimes 5 or 6 liters) than any other worker in this field whose work is reported. It is doubtful whether such large quantities are ever indicated or advisable inasmuch as good results have been recorded from the insufflation of even very small amounts (100 to 200 cubic centimeters) of oxygen or air. The dose of 500 cubic centimeters in children and of 1 liter in adults is well borne and appears sensible to us.

*Scott and Gleeten* report 3 cases of intestinal tuberculosis favorably treated by oxyperitoneum. The following is illustrative:

A male, aged 22 years, had abdominal pain and diarrhœa for 6 months. Fifteen injections of 400 cubic centimeters of oxygen at 10 day intervals were given. There was a complete subsidence of symptoms.

They conclude that the treatment is simple and harmless; that it relieves distressing symptoms of the ulcerative type of tuberculous enteritis, and if treatment is begun early, it may effect a cure.

*Purves and Bilcliffe* do not feel that the results are as good as reported by others. This opinion may be due to a poor selection of subjects for the treatment. They report 3 cases, 2 of whom died, and 1 was greatly improved by oxygen insufflation.

Case 1. Patient had plastic peritonitis with obstructive symptoms. Five oxygen insufflations were given. The patient was observed over a period of 1 year. Two relapses occured. Result: much improved.

Case 2. Patient had advanced pulmonary tuberculosis (a contra-indication to oxygen insufflation). After one injection, the patient died.

Case 3. The patient was diagnosed as a plastic peritonitis. Two insufflations were given but patient died from fæcal fistula.

*L. B. Hudson.* At laparotomy, a tuberculous peritonitis was found in a colored woman, Wassermann reaction was 3 plus. Several intraperitoneal oxygen insufflations were made with great benefit.

*Nelson Mercer.* The patient had an exudative tuberculous peritonitis and pulmonary tuberculosis. Three air insufflations were given 2 and 4 days apart, injecting 1500, 900, and 200 cubic centimeters of air after the removal of 1 liter, one-half liter, and another half liter of fluid. After 1 month all fluid had disappeared and the air absorbed. The condition of the patient was good.

*H. D. Meeker* reports a case cured for 4 years after a single oxygen insufflation following laparotomy in a 10 year old boy with tuberculous peritonitis.

*Von Moseiig-Moorhof (1893).* The patient observed had a tuberculous epididymitis and peritonitis; abdominal fluid was removed and air was injected; reported a cure.

*Nolen (1893)* reported 3 cases cured by air injections, one of which was a child with advanced intestinal tuberculosis.

*Jacobaeus* reported 5 cures in 6 cases of tuberculous peritonitis with air insufflation.

*E. Rost (1920)* reported great improvement in 3 cases after oxygen insufflation.

Fig 8. Tuberculous salpingitis. Oxygen pneumoperitoneum. (Author's Case 2.)

Fig. 9. Tuberculous salpingitis. Oxygen pneumoperitoneum. Calcification in tube and ovary. (Author's Case 6.)

*Weil and Loiseleur* report 3 cures and 3 failures with air insufflation. The failures are explained by active tuberculous foci elsewhere in the body. The 3 successful cases were followed up for a year; no ascites or adhesions formed. They believe that the results are equally as good after a single insufflation as when repeated treatments are given.

*Hayes* reports successful use of oxygen following relapse after laparotomy. He reports 10 cases in all only one of which, seen *in extremis*, died.

*Mount* reported 2 successful cases of oxygen insufflation from Mayo clinic after failure of laparotomy to cure.

AUTHOR'S CASE REPORTS

CASE 1. E. P., single girl, aged 19 years, was admitted to the gynecological service at Michael Reese Hospital on June 7, 1927. She had been operated upon 5 years previously for tuberculous peritonitis, and had been tapped several times since. The present illness began 7 weeks before admission with acute abdominal pain following an evening of dancing (during a menstrual period). This condition was first diagnosed as appendicitis, which subsided somewhat, but pain recurred every day or so. The pain again became severe 2 days before admission. Her past and family history were unimportant except as stated. Menses were always irregular and painful. Upon examination a median laparotomy scar was seen. The abdomen was distended and doughy, but no rigidity was present. Soft masses were palpable in both lower quadrants, and were slightly tender. Rectally a very tender hard mass filled the entire true pelvis. Tuberculous peritonitis involving the pelvic structures was diagnosed and medical management was instituted: bed rest, soft diet, quartz lamp therapy, and medical diathermy. Her temperature which was 103.2 degrees on admission ranged from 98.6 to 100.2 degrees next day, and continued so for a month. Her hæmoglobin was 70 per cent; red blood count, 3,100,000; white blood count, 9,200; and sedimentation time was 18 minutes.

After 1 month on this management, the status was quite unchanged except that the sedimentation time rose to 28 minutes. With the rotation of service, the patient came under the author's care. Examination on July 7, 1927, revealed a pale, thin girl with a large, adherent pelvic mass extending into both adnexa and involving the uterus. The same day 1250 cubic centimeters of oxygen was introduced using our usual (23) transabdominal technique and a pneumogram taken in the prone, partial knee-chest posture. The films (Fig. 4) revealed a large, dense mass with loops of bowel definitely adherent. Four days later the mass was found to be somewhat more mobile and slightly smaller, the general condition of the patient definitely improved, and there appeared still to be some oxygen in the peritoneal cavity. The temperature dropped to normal on the sixth day after insufflation and remained so. On the ninth day the patient had gained 2 pounds in weight, her temperature was normal, and the sedimentation rate was 33 minutes. Hæmoglobin was 80 per cent; red blood cells, 4,730,000; white blood cells, 9,600. On July 16, a second oxygen insufflation of 1000 cubic centimeters was given and was combined with an intra-uterine lipiodol instillation for further identification of the uterus and tubes in the mass. Films (Fig. 5) taken as above showed the mass slightly smaller, the uterine cavity displaced to the right, and both tubes patent permitting free intraperitoneal spill. (This is characteristic of tuberculous salpingitis.)

July 19, 12 days after the first oxygen insufflation, the patient was so well that hospitalization was no

longer needed. She was discharged with instructions to report at the outpatient clinic. On August 7, the patient reported that she felt well, had gained 5 pounds in 2 weeks, and that her temperature was normal; she was working daily. She was given 1250 cubic centimeters of oxygen intraperitoneally, and films showed reduction by one-half of the pelvic mass (Fig. 6). Sedimentation time was 1 hour and 30 minutes. On November 7, she had gained 12 pounds since her last treatment 3 months previously. One liter of oxygen was insufflated (Fig. 7). On May 24, 1928, she returned to the hospital for check-up examination. She states that she has had no pain and that her previously irregular menses are now normal, also that the dysmenorrhœa is cured. She gained 19 pounds in the 10 months since oxygen treatment was begun. Oxygen, 1000 cubic centimeters, was given chiefly for the purpose of obtaining a pneumogram, as the patient appeared quite healthy and the pelvic organs appeared normal to palpation. The films revealed only evidence of adhesions. On October 25, 1928, examination revealed the uterus as small, fixed, and retroverted. No adnexal masses were palpable. February 19, 1931, the patient felt well and asked whether marriage was advisable. The pelvis was negative except for a fixed retroversion.

On May 18, 1933, 6 years after oxygen therapy was begun, the patient is entirely well, has been working steadily for the past few years. The uterus is small, firm, and there is a third degree retroversion. The adnexa are negative. Cure has been established and maintained for 5 years since the last oxygen insufflation.

Case 2. A. G., aged 32 years, married 2 years, was apparently perfectly well until January, 1929, when she sought the author's advice because of childlessness. A small, fixed, retroverted uterus and no adnexal pathology were recorded. The cervix which was found to be eroded was treated by linear cauterization; 2 weeks later a pelvic mass developed and patient had a fever. Her husband, a physician, made a diagnosis of pelvic abscess. During the next few months, the cul-de-sac was drained through the vagina four times by other physicians.

Continuous fever, nausea, and vomiting, loss of weight, weakness, and a purulent, caseous discharge persisted until July 7, 1929, when the patient was admitted to Michael Reese Hospital on the author's service. The diagnosis was then made of tuberculous salpingitis, and on July 10, 1250 cubic centimeters of oxygen was insufflated into the abdomen for diagnostic and therapeutic purposes. Blood cultures and cultures from the suppurative vaginal sinus were negative. The pneumograph (Fig. 8) revealed a large uterus, a thickened and calcareous left tube, and an indefinite right adnexal involvement. The report of Dr. R. A. Arens, roentgenologist: "Transabdominal (oxygen) pneumoperitoneum discloses a large uterine mass almost entirely to the right of the midline. The uterine fundus appears smooth and round, but larger than the average. The left adnexa appears much increased in size, the tube being tortuous. The right tube is not seen. There also appear to be numerous adhesions in the pelvis. The films disclose the typical appearance of a salpingitis (left). From the peculiar density of the tube, tuberculosis must be considered."

The diagnosis of a right tubo-ovarian abscess (mixed infection) complicating tuberculous salpingitis was made. Oxygen insufflation (1000 cubic centimeters) was repeated on July 14. Each insufflation was followed by a day of lower temperature and apparent improvement, and then by a resumption of the septic course. An operation was deemed imperative for removal of tubo-ovarian septic mass.

Operation on July 22 included a right salpingo-oophorectomy for large tubo-ovarian abscess, appendectomy, separation of adhesions, and vaginal drainage, under spinal anæsthesia. Blood transfusion was given.

When the abdomen was opened, the right adnexa were found to be involved in a tubo-ovarian abscess 6 by 7 centimeters in diameter, anterior and to the right of the uterus. The appendix was adherent to the mass and about one-half inch of the tip of the appendix was buried in the abscess wall. The small gut was adherent to the mass and about the area of adherence many small tubercles were seen on the bowel wall. The left tube was thick, tortuous, and adherent to the bowel. Tubercles were also seen on the intestine at this place and on the left tube. The adhesions were separated, but the left tube and ovary were conserved with the hope of restoration. The mass on the right and the appendix were removed, and the large cavity in the right pelvis was packed with vioform gauze, the end of which was led into the vagina for drainage. Five hundred cubic centimeters of whole blood was transfused from the patient's brother before she was removed from the operating table. Typical tubercles were found on microscopic examination on the wall of the ovary and tube, and an acute (not tuberculous) purulent appendicitis. The postoperative course was satisfactory for 1 week when, after the gauze drain was removed *per vaginam*, a rectovaginal fistula was discovered. On August 8, 1929, an oxygen insufflation of 1000 cubic centimeters was made. A blood transfusion of 500 cubic centimeters was given on August 22. The patient continued to run a temperature to 102 degrees, a pulse of 104, and respirations of 22. The abdominal wound had healed by primary intention; drainage from the fæcal fistula had temporarily stopped. Rectal and vaginal examination on August 27 revealed no masses palpable in the pelvis, no evidence of fistula, and a soft abdomen. Consultation with Drs. Solomon Strouse and A. H. Curtis was had and the patient was advised to seek a change in climate. The patient left the hospital August 10, 1929, somewhat improved but weighing 103 pounds. The rectovaginal fistula had reopened and was discharging. After 5 months in Albuquerque New Mexico, she had gained 20 pounds and appeared in the best of health.

June 3, 1930, patient was in good health, and weighed 135 pounds. The uterus was movable. No palpable enlargement of the left tube was noticeable. There was a small area of granulation posterior to the cervix. November 20, 1930, her general condition was excellent, weight 145 pounds. The uterus and left adnexa were normal to palpation. Cervix and vaginal vault were clean. On August 28, 1933, according to a telephone report, the patient was feeling perfectly well. Menstruation was regular. Her weight was up to 165 pounds which she voluntarily reduced to 145 pounds.

CASE 3. (Courtesy of Dr. M. L. Leventhal) Michael Reese Hospital. H. P., aged 32 years, single, hospital technician. Patient complained of pain in both lower quadrants for 5 to 6 months, with nausea, vomiting, and temperature 102 degrees during attacks. Diagnostic pneumoperitoneum revealed a large cystic mass in the left half of the pelvis, with bowel adhesions to the uterus and the right adnexa. Operation was done on January 31, 1931, for left ovarian dermoid, and chronic pyosalpinx. Both tubes and an ovarian dermoid (15 by 15 centimeters) were removed. A small amount of serous fluid was present, and several small tubercles were noted on the tubes, bladder peritoneum, and broad ligaments. The report of the pathologic laboratory was acute and chronic tuberculous salpingitis; dermoid cyst of ovary. February 28, 1931, examination showed the uterus to be enlarged and tender.

March 6, 1931, oxyperitoneum—1 liter.

May 14, 1931, uterus small, anteflexed, partially mobile. Tender mass was noted in left. (Adhesions?) Oxyperitoneum, 1 liter.

May 27, 1931, still has tender mass adherent to the uterus on the left. General condition was greatly improved.

CASE 4. (Courtesy Dr. R. A. Reis) Michael Reese Hospital, February 7, 1932. Girl, aged 15 years, student, complained of pain in the lower abdomen and chest for 3 months. For the past month she had had night sweats. She had lost 18 to 20 pounds in 6 months. Menses began at 13 years and were regular until 8 months ago since which there has been an amenorrhœa.

Recto-abdominal examination revealed the cervix intact, uterus normal in size, erect, firm, tender, and fixed. Diagnosis of probable tuberculous salpingitis was made. An oxygen pneumoperitoneum for diagnosis and treatment was recommended. One liter of oxygen was used. The patient was readmitted March 31, 1932, for oxygen therapy. She had gained 3 to 4 pounds since her last treatment, and had night sweats no longer. One thousand cubic centimeters of oxygen was insufflated by transperitoneal route.

Examination on September 5, 1933: Patient has had no temperature or night sweats since treatment. She has gained 13 pounds in weight, has no pain, menstruation is normal. Bimanual examination showed that except for a small induration in the left parametrium, the uterus and adnexa are negative. Cure has been of 1 year, 7 months' duration.

Two additional patients with tuberculous salpingitis have been treated by the author with intraperitoneal oxygen therapy but records are incomplete concerning their subsequent course and the results obtained (Fig. 9 illustrates Case 6).

The object in presenting this subject at this time is to call to the attention of the medical profession of a safe and simple method of diagnosis and treatment of tuberculous salpingitis which has almost escaped general notice. We have cited briefly 64 cases of intra-abdominal tuberculosis from the literature—an incomplete list, to be sure, and have reported 6 additional cases. Two of these represent cures of 4 and 5 years, respectively. In utilizing oxygen therapy, one must not lose sight of the other factors so valuable in the care of the tuberculous patient, namely, rest, climate, food, and tonics as indicated, and surgery when the condition is complicated by mixed infection. It is evident from some of the case reports cited that intraperitoneal oxygen insufflation is valuable in intestinal tuberculosis and various forms of tuberculous peritonitis if used in the early stages. Terminal infections, moribund patients, or those with advanced pulmonary disease are unsuited for this method.

Whenever tuberculous salpingitis is suspected it is advisable to utilize oxygen pneumoperitoneum for diagnostic purposes, the films rendering valuable aid in recognizing the pathology; the oxygen at the same time serves a double purpose, being a valuable therapeutic agent. This is readily appreciated by those who employ the method, as the patient shows prompt evidence of improvement. Temperature falls to normal in a few days, pain is less, the patient feels stronger and begins to gain weight at once. In some instances a single insufflation is enough as reported by Lucherini. In others repeated doses may be required, as indicated by the patient's course.

## SUMMARY

Oxygen pneumoperitoneum is recommended in tuberculous peritonitis whether primary or of genital or intestinal origin. It is of value for diagnosis chiefly in tuberculous salpingitis, and in intestinal adhesions in the pelvis. It may be combined with the use of iodized

oil instillation when one desires to visualize the uterine cavity and fallopian tubes. The tubes are usually patent in tuberculous salpingitis. The insufflation is used both diagnostically and therapeutically; the method of transabdominal puncture is simple and safe.

Sixty-four cases of therapeutic pneumoperitoneum are cited from the literature and six additional cases are reported to attest the value of oxygen pneumoperitoneum in intra-abdominal tuberculosis. We urge that all patients be given oxygen insufflations as a therapeutic test before being subjected to laparotomy.

## BIBLIOGRAPHY


1. Bainbridge, W. S. Am. J. Surg., 1913, xxvii, 364; 1923, xxxvii, 52.
2. Curti, O. P. Semana méd., 1926, i, 1263.
3. Hayes, E. W. Lancet, 1924, xliv, 571.
4. Hertzler, A. E. The Peritoneum. St. Louis: C. V. Mosby Co., 1919.
5. Hudson, L. B. Surg. J., 1927, xxxiii, 138.
6. Jacobaeus. Ueber Laparo. und Thoraskopy. 1913, lxvii, 73.
7. Kelly, H. A. Operative Gynecology, 1914.
8. Koenig, F. Centralbl. f. Chir., 1884, xi, 81.
9. Lauenstein. Quoted by Maylard. Abdominal Tuberculosis, p. 310. Philadelphia, 1908.
10. Lucherini. Policlin., 1927, xxxiv, 1281.
11. Maestrini, D. Riforma med., 1925, xli, 827; 1926, xlii, 892.
12. McGlinn, J. New York M. J., 1908, lxxxviii, 359.
13. Meeker, H. D. Int. Surg., 1912, xxv, 247.
14. Mercer, N. Virginia M. Month., 1926, liii, 157.
15. von Mosetig-Moorhof. Quoted by Maestrini.
16. Mount, H. T. B. Canadian M. Ass. J., 1931, xxv, 309.
17. Norris, C. C. Gynecological and Obstetrical Monographs. Vol. xi. New York: D. Appleton & Co., 1931.
18. Purves and Bilcliffe. Brit. M. J., 1924, i, 906.
19. Santorsola, D. Policlin., 1927, xxxiv, 636.
20. Scott and Gleeten. Atlantic M. J., 1925, xxix, 183.
21. Silvestri, T. Riforma med., 1926, xli, 1105.
22. Stein, A. J. Am. M. Ass., 1922, lxxviii, 718.
23. Stein, I. F. Pelvic diagnosis by roentgen visualization. Surg., Gynec. & Obst., 1932, lv, 207; J. Michigan State M. Soc., 1931, xxx, 675; Am. J. Obst. & Gynec., 1931, xxi, 671.
24. Stein, I. F., and Arens, R. A. Visualization of the pelvic viscera. Radiology, 1930, xv, 85.
25. Idem. Pneumoperitoneum in gynecology. Radiology, 1926, vii, 326; 1927, viii, 494; 1929, xii, 341.
26. Tremiterre, S. Riforma med., 1926, xlii, 561.
27. Weil and Loiseleur. Quoted by Tremiterre.
28. Wells, Spencer. Ovarian and Uterine Tumors. London, 1873.

# THE X-RAY IN THE STUDY OF THE CATGUT LIGATURE

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MANY obscure ancient writings indicate that the idea of ligating vessels with cords was age old when Galen in the first century described the use of silk and catgut for the purpose. Recorded research in the art appears periodically from that time on. One of the important contributions was that of Ambrose Paré (1517–90) who standardized on the systematic use of the ligature in operations instead of actual cautery.

The first detailed research on absorption is sometimes credited to P. S. Physick, a professor of surgery in Philadelphia. About 1816 he demonstrated the superiority of catgut over flax or silk for ligating due to its disappearance in the wound. His experiments were started on the horse and were later transferred to humans. About 30 years later this work was greatly amplified by Luigi Porta who occupied the chair of surgery at Pavia. Porta described the results of 600 experiments on 270 animals using catgut, silk, hair and hemp as ligatures.

Despite these scattered early experiments, however, research in the field really began with Joseph Lister (1869). It was Lister's paper that first referred to the use of antiseptic catgut and it was the opening gun of a tremendously active period in surgical gut research that has extended right down to the present time.

As was natural, the trend of the research following Lister's work was in the direction of sterility and for many years the literature was crowded with papers on this subject.

All the while the use of catgut in surgery was increasing by leaps and bounds and commercially manufactured gut began to replace the home made article of the surgeon. With the advent of the manufacturer, new research was introduced into the picture, which work, though largely unpublished, has been of inestimable value to the surgical profession.

Processing techniques, sterilizing techniques, and exact tests on products have all been rather thoroughly covered by the better ligature manufacturers. In addition several manufacturers have sponsored research programs at medical schools on subjects pertaining to the use of catgut in surgery.

All of this research, however, has dealt with the macro aspects of the ligature. After reaching a certain point, further knowledge of the product had to await the development of research tools and techniques that permitted examination of the ultimate structural characteristics of these protein fibers.

## A NEW METHOD OF STRUCTURAL STUDY OF SUTURES

Our knowledge of the chemistry of proteins has been decidedly fragmentary, and certainly definite information as to how protein molecules build themselves into solid animal tissues so as to account for complex behavior is almost entirely lacking. The microscope has been useful in disclosing gross structural features. By splitting up collagen fibers such as those which constitute catgut sutures, by means of swelling experiments it has been demonstrated that there are fiber bundles, built up from 5 to 10 fibers; and each fiber is built up from about a hundred fibrils. These tiny fibrils are the real collagen units and yet the microscope is able to say nothing as to the still smaller and more fundamental units which comprise the fibril.

It is obvious that the desired properties in sutures and ligatures of highest quality reside in structural units which are below the resolving power of the microscope. The polarizing microscope indicates the anisotropic nature of the collagen fibers but there is little or no differentiation possible on the basis of quality. Therefore, information on the ultimate fine structure of these protein materials must be sought by other methods. The X-ray has provided a method for studying these structures and one of the newest research techniques is that of X-ray diffraction.

The X-ray diffraction method enables the examination of ultimate structure of materials in the sense of a supermicroscope. Since the X-ray wave lengths employed are only 1/6000 as long as yellow light, and both the X-ray and light are diffracted by suitable gratings, the range of subdivision detected is at once indicated. All crystalline substances serve as three-dimensional diffraction gratings for the X-ray, because the atoms and molecules lie upon parallel planes which are spaced apart at distances comparable with the X-ray wave lengths. The diffraction pattern obtained for any crystalline substance depends, of course, on the arrangement of ultimate building units characteristic of the substance in question. Consequently, the pattern can be interpreted in terms of the actual ultimate constitution and fine structure of any material. The steps in such an interpretation of a pattern for a catgut ligature will be illustrated later. The fundamental law involved is expressed by the formula $n\lambda = 2d \sin \theta$—where $n$ is a whole number, $\lambda$ is the known X-ray wave-length (for this work ordinarily the $\alpha$ ray of copper, 1.54 Angstroem units), $d$ is the spacing of a set of parallel planes which build up the material, and $2\theta$ is the experimentally measured angle of a diffraction interference corresponding to the given set of parallel planes.

The experimental technique for X-ray diffraction analysis of ligatures is comparatively simple as illustrated in Figure 1. An actual apparatus is photographed in Figure 2. A monochromatic beam of X-rays defined by small pinholes (about .025 inches in diameter) is passed through a ligature specimen perpendicular to the fiber axis. A photographic plate is adjusted at a fixed distance behind the specimen, usually 5 centimeters. After development of the film the characteristic pattern appears and in accordance with straight forward principles is measured and interpreted in terms of ultimate constitution and structure so that a model can be constructed.

Significant results have already been obtained from the use of this, one of the newest of research tools:

1. It has been demonstrated that the raw material received by the catgut manufacturer is extremely variable in structure and thus the technique provides a possible basis for selection of raw material.

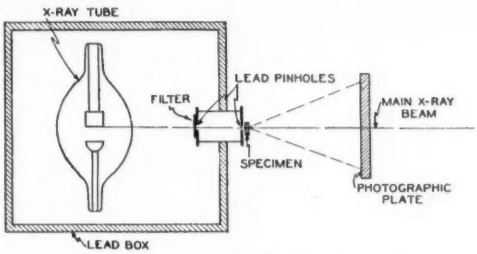


Fig. 1. Diagram of diffraction apparatus.

2. Catgut structures that go hand in hand with high tensile strength and definite absorption characteristics are easily differentiated from other structures that give low strength and a different absorption curve.

3. It has been demonstrated that it is possible by suitable techniques to alter the structure of catgut. Thus it is possible to go from a less preferred to a more preferred orientation or vice versa.

4. Catgut processing by the manufacturer has a tendency always to change the structural picture usually to a less preferred arrangement of units.

5. A more exact knowledge of the mechanism of chromicizing is an outgrowth of the work.

## THE SIGNIFICANCE OF A DIFFRACTION PATTERN

Before attempting to interpret the X-ray diffraction pattern which is characteristic of a protein fiber such as a catgut ligature, it will be well to select as an example another well known natural substance cellulose, the structure of which has been worked out with amazing completeness from X-ray data. Figure 3 reproduces the pattern from ramie fibers, one of the varieties of cellulose, made by the same technique as already outlined which is utilized for the suture studies. Without examining in detail all the steps in the analysis of the pattern we may outline the definite facts of ultimate structure which are discovered and universally accepted at the present time.

a. In the first place these ramie fibers are

very definitely crystalline, or at least contain primarily a crystalline constituent known to be pure cellulose, otherwise there would have been possible no such beautifully symmetrical and sharp a pattern indicative of diffraction of X-rays by a three-dimensional grating constituted from molecules marshalled in a lattice work.

b. The pattern definitely proves that the ramie fiber is not a single crystal but is built up from a great number of very small crystal units, called crystallites or colloidal micelles, which, however, are all arranged in space so that a common direction in them is parallel to the axis of the fiber. In other words this is a case of a high degree of *preferred orientation* or *fibering*. Just to show what happens to the X-ray pattern when we have a specimen composed of these same little cellulose crystallites arranged *at random* instead of being all oriented in one direction, we may compare Figure 4 for cellophane with Figure 3 for ramie. Cellophane is a brush-heap arrangement of cellulose crystallites; ramie is a sort of chimney built from perfectly arranged bricks. Cotton represents an intermediate state of preferred orientation of these tiny cellulose units as a casual glance at Figure 5 will at once show. These examples illustrate how the X-ray patterns can differentiate between orientation of the same crystal units.

c. Careful comparison of the greatly different patterns for ramie, cellophane, and cotton will reveal, however, certain fundamental identities which prove that all these materials are cellulose. The diameters of the rings upon which the sharp spots in the ramie pattern lie are the same as the ring diameters in the cellophane and cotton patterns. Irrespective of the orientation of the various little crystallites which in a sense are like the grains of sand in a rod of cement concrete, the pattern enables us to tell how each grain is built up from still smaller units, namely molecules and atoms. The pattern tells us, for example, that the very smallest unit of volume which is still cellulose, in other words the real architectural building unit, is a parallelopiped with edge lengths of about 7 by 8 by 10 ten-millionths of a millimeter. This unit cell contains 4 dehydrated glucose $C_6H_{10}O_5$ groups arranged in a perfectly definite way, the X-ray data telling us exactly where each carbon and oxygen atom is in space. Of course the larger crystallite is built up from the multiplication of this unit cell in all directions. Furthermore we find that a large number of these $C_6H_{10}O_5$ groups are bound together, with oxygen atoms serving as bridges, into long chains. Now the crystallite or micelle is simply a bundle of these long chains. The length of the micelle which we may also measure from the X-ray pattern is determined by the chain lengths and is about 50 times as long as the side of the little unit cell (about 10 Angstroem units) and the cross section of the micelle is determined by how many chains are in a bundle, and is usually about 50 Angstroem units. So we have the single ramie or cellulose fiber built up from long rod-like crystallites which are about ten times as long as they are thick; these in turn are built up from bundles of long chain molecules; these in turn from a unit crystal cell far smaller than these molecular lengths simply because there is a definite periodicity along the chains; the cell is built up from dehydrated glucose groups, which finally are constituted of carbon, hydrogen and oxygen atoms.

It is needless to point out how extremely valuable this fundamental information concerning the building plan of cellulose has been. The practical properties of materials depend absolutely upon these facts. Suffice it to say that the improvement in the tensile strength of commercial rayon in recent years has been the result of X-ray diffraction research. What a given manufacturing process does to a material is immediately indicated by the pattern serving as a supermicroscope.

### DIFFRACTION PATTERNS FOR CATGUT LIGATURES

Upon the basis of the foregoing discussion of a typical diffraction pattern which has been extensively studied and fully interpreted, it is possible to approach intelligently the interpretation of patterns for ligatures which have not been subjected to any appreciable amount of study. An average diffraction pattern for a commercial catgut suture is reproduced in

Figure 6 and a graphical representation which may be somewhat more easily described in Figure 7. The principal features of this pattern proceeding from the center out are as follows:

a. In the center of the pattern appears the trace of the undiffracted main X-ray beam, from which point of course the angles $2\theta$ are measured.

b. A general fogging of the film near the central spot at small angles due to scattering of the rays by truly amorphous material present in the specimen. The intensity is a measure of the amount of amorphous matter as compared with the more definitely crystalline constituents.

c. Two inner arcs lying equatorially on the same circle. This diffraction ring corresponds to a spacing between crystal planes of 11.9 Angstroem units. The great significance of the lengths or sharpness of these arcs will appear in a later paragraph.

d. A broad halo evidently due to a part of the collagen in the ligature which is essentially amorphous or at least much less well organized than the crystalline portion responsible for the sharp interference maxima. The spacing corresponding to this halo is about 4.3 Angstroem units and is evidently quite common for proteins, where arrangement on equidistant planes is quite imperfect. Even for this constituent there is a tendency toward preferred orientation or fibering as indicated by the marked bulging of the halo on the equator of the diffraction pattern. In some cases this broad halo is observed to split into two sharper rings.

e. An outer sharp ring usually appearing as two arcs at the poles is an indication of a fiber crystalline constituent and a spacing of 2.8 Angstroem units.

f. In certain cases in which the ligature has been subjected to an unusual degree of tension there appear on the pattern between the inner sharp arcs and the broad halo four sharp spots or arcs lying on the same ring. As will be demonstrated later the appearance of these spots which are not present for the usual catgut specimens has a profound significance in terms of properties and performance of the suture.

### POSSIBLE VARIATION IN DIFFRACTION PATTERNS FOR DIFFERENT SUTURE SPECIMENS

With the average diagram for a catgut ligature thus described it is possible now to enumerate the variations in the patterns which have been observed in comparative studies of different specimens and to understand the general significance of these variations.

a. The amorphous scattering or fogging near the undiffracted beam which indicates truly amorphous matter may vary from practically zero intensity to a very marked blackening of the film, showing an almost continuous variation between specimens containing little or no amorphous matter to those which are almost completely broken down, for example, by heating or by digestive processes.

b. The innermost sharp ring, of all features of the pattern, is most sensitive to variations in specimens which appear to be very similar. The arcs which appear ordinarily on the equator of this inner ring may be so long actually as to form a continuous ring. In this case the crystal units responsible for this interference would be distributed at random in much the same way as cellulose crystallites are arranged in brush-heap fashion in cellophane. On the opposite extreme these arcs may actually be so sharp and short that they appear simply as spots lying on the equator of the pattern. In this case the crystal units must be oriented in a nearly perfect preferred direction parallel to the axis of the fiber.

Between the two extremes described every possible arc length might easily be observed in different specimens. It is evident, therefore, that the length of these arcs is very definitely a measure of the degree of the preferred orientation of the crystalline particles or colloidal micelles which build up the protein collagen fibril. Different ligature specimens can be compared therefore by relative measurements of arc lengths. This comparison may be made strictly quantitative by a new method worked out by Clark and Sisson. A microdensitometer with rotating stage is employed. The film is adjusted so that it may be rotated with this inner circle in focus and successive readings can be made of the actual density of the photographic emulsion which is plotted as a

function of an angle. A curve can thus be drawn whose width is a quantitative measure of the length of the arc. This curve may then be treated mathematically to give definite numerical values, expressing the perfection of orientation of the micelles. These numerical values are highly significant in that they run parallel with measured physical properties such as tensile strength. Other things being equal the shorter and sharper these arcs, indicating high degree of preferred orientation, the greater the tensile strength of the fibril. This is true not only of cellulose but also of these protein collagen fibers, silk, keratin, etc. The fact that it is possible with any given suture specimen to change these arc lengths by suitable chemical and mechanical methods has given to this X-ray research method an even greater practical significance.

c. Running somewhat parallel with the inner arcs the protein halo may vary from a continuous band of uniform widths representing random distribution to a very high degree of preferred orientation even for this imperfectly organized material. In this case the equator of the band becomes very broad and many times appearing as marked bulges on the band while the polar parts of the band become narrow and quite faint.

d. The lengths of the arcs on the outer sharp ring appearing at the poles may also vary from a continuous circle to short lengths, indicating preferred orientation.

e. It is significant that variations in the widths of the two principal sharp rings and the halo may also be observed as well as variations in lengths. The widths of the interferences are dependent upon the size of the crystalline particles or micelles; the broader these maxima the smaller both in length and cross section are these colloidal particles. If we assume for a moment that collagen is built up somehow from long chains similar to those of cellulose then it follows that any rupturing of these chains, or breaking down into shorter molecules and smaller colloidal particles would show by an increase in width of the lines or spots appearing on the pattern.

f. A very significant variation in patterns is the appearance or non-appearance of an additional diffraction ring which appears simply as four sharp arcs between the inner ring of small diameter which is always present and the broad halo. The appearance of these new spots is always associated with the shortest and sharpest arc lengths on the other rings—in other words, with the highest degree of fibering. In general the appearance of these new interferences then would indicate sutures of unusual quality especially as regards tensile strength. They appear only very occasionally in ordinary commercial specimens of raw catgut or of finished sutures, but it is significant that they can be made to appear by certain developed techniques. This process will be considered in a later section of the paper. Having now considered the possible variations in a diffraction pattern which we might observe by a comparison of various specimens we may now proceed to examine the significance of this diffraction pattern in terms of how a protein fibril is built in the ultimate sense and how actual specimens, all built from the same fundamental units of familiar chemical composition, may yet vary markedly in architectural and in physical, and even chemical, behavior.

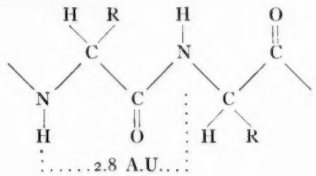
### THE RELATION OF SUTURE DIFFRACTION PATTERNS TO X-RAY RESULTS ON COLLAGEN AND GELATIN

The catgut ligature pattern is in general agreement with that of collagen and gelatin which have been known for several years.

Thus for a dried block of gelatin there are observed two sharp rings corresponding to crystal dimensions of 11.9 and 2.8 Angstroem units, and a broad halo for an amorphous part with the spacing 4.3 Angstroem units, exactly as found for fibrous catgut and collagen. Furthermore gelatin may be stretched as much as 200 per cent yielding a fiber pattern with the new additional sharp spots between the innermost ring and the broad halo which is practically indistinguishable from that of catgut or fibrous collagen. An additional spacing, the identity period along the fiber axis, may now be determined from the layer line diagram. This is 9.5 Angstroem units. Hence two of the three dimensions of the unit crystal cell containing the crystalline protein are 9.5 and 11.3 Angstroem units.

### FUNDAMENTAL CONCLUSIONS ON PROTEIN STRUCTURE

Natural silk fibers formed from the protein fibroin were the first studied by X-ray methods to give a clue as to the problem of the structure of the protein molecule as a whole. Natural silk does not give such a complete fiber diagram as that of cellulose but Meyer and Mark applied to it principles learned from the latter and suggested that the fibroin crystallites also were no other than bundles of long molecular chains. Just as the long chains in cellulose consist of a repeating unit of the dehydrated glucose residue so the protein chain is built up from units mainly joined through peptide linkages. The remarkable studies on stretched wool and hair by Astbury and by one of the writers give further definite confirmation to this conception. The result is a long polypeptide chain with the length of the repeating unit usually 3.5 Angstroem units, although this varies somewhat with the protein, and is probably 2.8 for catgut. This is illustrated diagrammatically as follows:




In this diagram "R" represents any side group attached to the main backbone chain. These groups differ from one protein to another and, of course, serve to distinguish the behavior, particularly as regard swelling in water of various types of proteins. The diffraction pattern for catgut ligatures or collagen fibers then relates itself directly to the more definitely crystalline patterns for silk and stretched keratin. Poor as the photographs are when judged by standards of ordinary crystalline analysis, the fact that any pattern at all is obtained suggests that there must be a crystalline part of the fiber substance. The sequence of amino acid residues cannot be extremely irregular. Only a fraction of the fiber substance is in such a definitely crystalline state as to contribute to the

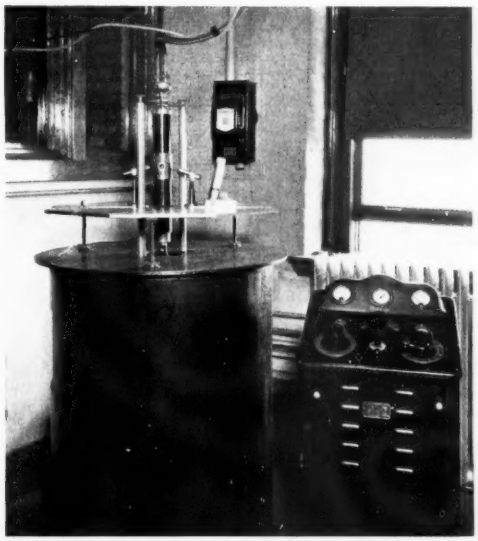


Fig. 2. Photograph of diffraction apparatus.

photograph proper, and it is an interesting and important point as to how far the X-ray indications apply to the fibril as a whole. The most reasonable point of view as pointed out by Astbury is that there is no such thing as a pure chemical protein in the ordinary chemical sense but that the X-ray photograph presents an ideal toward which the structure approximates.

The setting of a gelatin sol to a gelatin jelly is associated with a change in the X-ray diffraction patterns, as has been observed frequently in this work. The diagram for the sol indicates an amorphous structure, while the jelly has well defined rings characteristic of crystal structure. Jelly formation is, therefore, due to development of some degree of organization. Knowledge of actual structural constitution of a catgut fiber is aided very materially by studies of swelling. These observations which will be reported elsewhere in detail, together with the characteristic X-ray diffraction pattern, suggest that the catgut collagen fibril is composed of a bundle of the protein molecules arranged with backbones parallel to the long axis of the fibril and held together by co-ordinate linkages between backbones of adjacent molecules. Thus col-

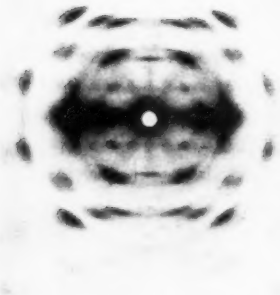


Fig. 3. Diffraction pattern for ramie (cellulose) fiber.

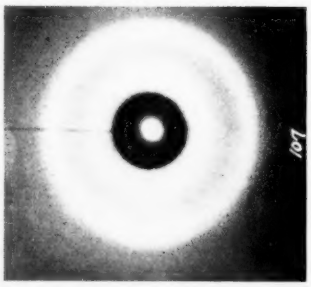


Fig. 4. Pattern for cellophane.

lagen differs from gelatin only in this very definite arrangement of the long chains. Strong cohesive forces of these molecules in such definite arrangement serve to reduce the swelling of collagen in water to a very much lower value than that of equally concentrated jelly under the same essential conditions. It follows from all the evidence that the hydration or swelling of proteins depends upon chemical constitution of chemical molecules and on molecular organization, the latter being the significant factor which differentiates catgut from gelatin. This so called molecular organization increases step by step in the following list of protein substances: gelatin, muscle, catgut, wool keratin, horse hair keratin, and fibroin silk gut. It follows then that the swelling and hydration, as well as other physical properties, such as tensile strength, for the same protein will be conditioned by the degree of fibering as for example, in catgut ligatures. This can be controlled. The practical behavior also should be subject to control. Experimental results on this point are presented in a later section.

We must conclude from all the data available, therefore, that the catgut ligature is built according to an architectural plan exactly as cellulose is built, even though from vastly different chemical substances. Crystallites, or micelles, are built up from long chains held together in bundles. These bundles tend to be oriented in a common direction parallel to the axis of the fibril in a greater or less degree of perfection. The micelles tend to hold each other in position by virtue of active chemical groups on the surfaces of the particles which are extensions from the backbones; and even the fibrils in a fiber exercise certain attractive forces upon each other, which materially affect the ability to absorb water or other reagents. These micelles or bundles thus may be pictured as somewhat elastic or worm-like rods because of the nature of the protein chain. The X-ray spacings correspond to a definite direction along the chains or to the cross section of a bundle of chains.

It follows then that the swelling and hydration as well as other physical properties for the same protein will be conditioned by the *degree of fibering*. If, for example, in catgut ligatures this can be controlled, the practical behavior also should be subject to control.

The foregoing discussion of protein structure while still imperfectly understood in detail has been derived from repeated X-ray determinations. Clark, Bucher and Lorenz have used the X-ray diffraction method in the study of normal and pathological human tissues, including stretched and unstretched tendons and muscles. Extension of these specimens always results in a parallel alignment of long protein molecules and typical fiber diffraction pattern. This has been demonstrated even on living frog muscles excited to tetanus contraction. Cancerous tissues show patterns which differ from those for normal tissue, thus proving a changed molecular constitution and form. These experiences have thus permitted a logical and intensive investigation upon the whole

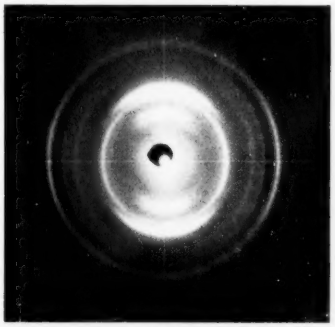


Fig. 5. Pattern for cotton fiber.

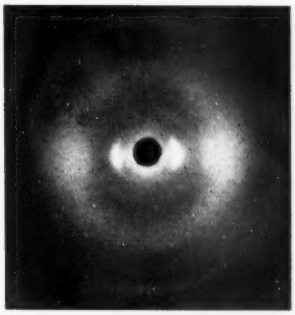


Fig. 6. Pattern for average catgut fiber.

problem of surgical ligatures. The present paper is limited to the usual type of collagen "catgut" ligatures, starting from the raw material derived from the intestinal walls of sheep.

### A COMPARISON OF RAW CATGUT AND FINISHED LIGATURES FROM VARIOUS SOURCES

All raw catgut and finished ligature specimens yield diffraction patterns characteristic of protein collagen with unit cell dimensions already noted. Specimens are differentiated from each other, however, with great sensitiveness by the degree of preferred orientation of the micelles with respect to the long axis of the fiber. This is measured especially well by the length of innermost equatorial arcs which correspond to the 11.9 Angstroem units dimension. Figure 8 reproduces patterns of raw catgut and Fig. 9 of commercially competing finished ligatures to illustrate the wide variation possible.

The following general conclusions may be derived from a large number of X-ray studies.

a. Raw catgut has a higher degree of preferred orientation than any specimen following further processing, provided that tension and stretching are not applied during processing. Elevated temperatures and swelling treatments invariably disarrange a parallel micellar arrangement to a greater or less extent.

b. Commercial catgut samples are distinguished chiefly by the lengths of arcs on the inner sharp diffraction ring. A rating on performance as to tensile strength, uniformity, and absorption time in the tissues can be made from patterns. In general, the shorter and sharper the arcs on the inner interference ring, and the narrower the corrected microdensitometer curve the stronger the ligature, other things being equal. X-ray patterns show remarkable differences between ligatures from different manufacturers, and in some cases in different lots from the same manufacturer while other commercial ligatures are remarkably consistent. Variations in raw material and the slightest differences in any chemical treatment, tension or temperature all change the structure and the controlling X-ray pattern.

### THE EFFECT OF TENSION ON CATGUT

If the structure pictured for catgut is true, and it explains all known facts of behavior, it should be possible by suitable tension on the

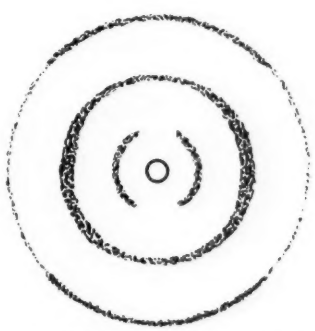


Fig. 7. Drawing of pattern for catgut.

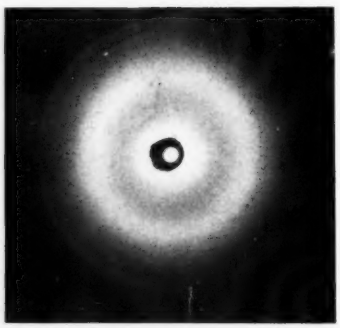


Fig. 8. Pattern showing no fibering or preferred orientation in catgut suture.

catgut fiber rendered plastic by swelling agents, to pull the micelles into still more perfect alignment. The X-ray diffraction pattern proves this to be the case, for the pattern not only shows sharper fiber intensity maxima but four new intensity maxima symmetrically arranged between the inner crystal ring and the amorphous halo.

This diagram indicates a degree of symmetry superior to that observed for most ordinary commercial catguts; there is distinctly an axis of orientation parallel to the direction of tension and stretching, and the structure approaches that of a well oriented crystalline substance. The new intensity points enable very accurate calculation of the identity period along the fiber axis, namely about 9.5 Angstroem units. In other words, some combination of atoms along the complex polypeptide chains repeats itself. Another dimension or cross section of the unit crystal cell is the 11.9 Angstroem units deduced from the inner spots. Without assumptions the third dimension cannot be directly deduced. Such a pattern, however, is obtained only under these conditions of swelling and tension. One or two samples of raw catgut have shown faint evidence of the four points which appear only for excellent orientation, evidently in instances in which unusual tension in drying has been employed.

Further processing into final sterile ligatures always has a tendency to remove this evidence and consequently to leave less perfect orientation.

### THE RELATIONSHIP BETWEEN STRUCTURE AND TENSILE STRENGTH

Experiments on rayon indicated that when the cellulose filament was regenerated from solution under tension, the micelles were more perfectly aligned than in ordinary varieties as indicated by a far more highly fibered diffraction pattern, and the tensile strength was considerably enhanced. The surface forces of the micelles were able to bind the micelles into a strong unit as compared with a brush-heap micellar arrangement. Similarly cotton which has been swollen and stretched in the solid phase becomes stronger by 50 per cent or more. Some typical data as to the effect of good orientation on tensile strength are as follows:

| Material | In Kg./mm² |
|---|---|
| Cast iron | 20 |
| Steel | 170 |
| Copper wire | 40 |
| Aluminum | 10 |
| Lead | 3 |
| Wood in fiber direction | 8–15 |
| Silk | 35 |
| Cotton | 28 |
| Ordinary viscose rayon | 25 |
| Well oriented viscose rayon | 80 |
| Ordinary acetate silk | 18 |
| Well oriented acetate silk | 100 |
| Ordinary rubber | 15–20 |
| Rubber (well oriented) | 80 |

Bergmann and Jacobs have shown for a band of gelatin the following:

| | | |
|---|---|---|
| Gelatin unstretched | 4.4 | kg./mm² |
| Gelatin stretched 300 per cent | 9.3 | |

For tendons or fibrous collagen the following data have been obtained by Vance:

| | | |
|---|---|---|
| Tendon (swine) | 11.0 | kg./mm² |
| Same heated and shrunk at 80° (X-ray fiber pattern disappears) | 3.0 | |
| Stretched again to original length | 10.6 | |

The shrunk and stretched tendons are thus exactly analogous to rubber. That the chains on the stretched tendons lie in the fiber direction can also be shown by freezing. There is a marked cleavage in the fiber axis, while the shrunk tissue breaks into clumps. By heat treatment, therefore, the principal valence chains change their form and become rolled up and the X-ray pattern disappears. The same effect can be accomplished on catgut by swelling media.

The X-ray pattern of catgut ligatures should therefore be an indication of tensile strength—the more strongly fibered or perfectly oriented, the stronger in general. Hence, the process of stretching catgut, leading to the appearance of the four new interference points (the most sensitive and accurate criterion) should be accompanied by changed mechanical properties and enhanced strength.

Tensile strength is obviously a function of gauge or diameter, strength increasing with gauge. If it were possible to decrease the gauge of any given strand of gut without causing a change in tensile strength in effect the ratio of strength to gauge would be increased. With this in mind a series of experiments were carried out to determine if improvement in tensile strength could be effected by drying catgut while the length is maintained constant, which in effect introduces tension, or even with the maximum tension possible. To this end a number of strands of raw catgut representative of a production lot were selected and thoroughly wetted. One half of each original strand was then allowed to dry under room conditions except that tension was applied.

Subsequent measurements proved that, on an average, the application of tension caused a reduction in gauge or diameter over that of gut dried without tension. A direct comparison of strength data as obtained indicates that strength is slightly improved by tension drying. However, a comparison after correction for variations in gauge points to a marked increase in strength per unit gauge for gut dried under tension. The tension dried gut showed the more preferred micellar orientation.

In continuing the study of the effect of drying under tension a series of experiments were made on plain non-boilable catgut. This product may be considered as raw catgut which has been subjected to an elevated temperature for a period of hours. This process removed all moisture from the gut. Experiments were made directly after removal of the gut from a 98 per cent alcoholic solution in which it had been stored for periods ranging from 6 months to 4 years. In all cases

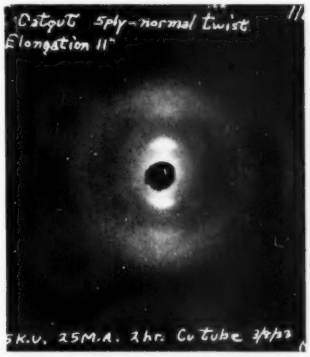



Fig. 9. Pattern showing opposite extreme of excellent preferred orientation.

swelling was perceptible and the gut stretchable. Other experiments were also made on gut which had been allowed to swell in water or water solutions of various swelling agents.

Here, again, as with raw catgut the application of tension to gut while swollen and its maintenance under that condition while drying resulted in improved tensile strength.

## THE RELATION BETWEEN STRUCTURE AND ABSORPTION

Closely related are the relationship between structure and chemical attack. When rubber is strongly stretched or racked not only is the tensile strength increased but also the swelling properties changed. Such racked threads can remain for long periods in the usual rubber solvents, such as chloroform, without being attacked. Strongly oriented cellulose fibers also resist swelling and are dyed with difficulty. So in catgut ligatures the time of digestion by tissue fluids or by standard tryptic enzymes should be related to structure, especially as regards time required for penetration and swelling of the fiber. This is proved by the fact that ligatures near knots remain after other portions are digested. X-ray patterns show that at knots an improved preferred orientation is produced by the tension so exerted.

## SUMMARY OF COMPARISONS OF LIGATURES FROM X-RAY DATA

1. Raw catgut has a higher degree of preferred orientation than any specimen follow-

ing further processing. Elevated temperatures or swelling treatments invariably disarrange a parallel micellar arrangement to a greater or less extent.

2. Commercial samples are chiefly distinguished by the lengths of arcs on the inner sharp diffraction ring. A rating on performance as to tensile strength, uniformity and absorption time in the tissues undoubtedly can be made from the patterns and a measurement of these arc lengths—the shorter and sharper the stronger the ligature, other things being equal. X-ray patterns show remarkable differences between ligatures from different manufacturers, and in two or three cases from different lots from the same manufacturer while other commercial ligatures are remarkably consistent. Variations in raw material, and slightest differences in any chemical treatment, tension or temperature all change the structure and the controlling X-ray pattern.

3. Carefully regulated swelling and tension produce a characteristic effect in the X-ray patterns which has been described. Any ligature which shows clearly the four point diagram between the inner ring and the "amorphous" halo may be said to have a high degree of preferred orientation, and probably superior tensile strength and definite absorption characteristics. These orientation interference points appear rather suddenly and only when tension has been applied. Normal gelatin, tendons, or collagen specimens do not show them. As orientation improves the innermost and outermost area shorten progressively to a point where the 4-point layer line diagram appears. The importance and significance of this phenomenon in rating ligatures cannot be overestimated.

4. Interesting changes are observed when ligatures are planted in animals and allowed to undergo digestion by body fluids. Knots present greatest resistance because, as proved by X-ray analysis, preferred orientation is enhanced by the tension of the knot. For straight lengths subjected to varying digestive action, various types of diffraction patterns suggest that the process is something as follows:

a. The "Amorphous" portion, consisting of shorter molecules statistically disorganized, is first attacked. The amorphous halo decreases in intensity in comparison with the sharp crystalline rings, and becomes somewhat sharper and definite as the "sorting" process proceeds. The crystalline portion and the parallel orientation is unaffected.

b. As the cementing amorphous material disappears the crystal micelles become disarranged and the arcs increase in length progressively until practically continuous rings indicative of random orientation appear.

c. In the final stages the sharp crystalline rings become less definite and amorphous scattering or fogging near the center show the disintegration process of both crystal micelles and disorganized matter initially present.

5. The diffraction pattern of chromicized gut is very similar to the untreated material. In general, a somewhat better preferred orientation of crystal micelles than in ordinary ligatures is observed. The chromicizing treatment evidently tends to hold the micelles in position and to offset swelling or temperature effects.

6. New crystalline compounds or evidences of inorganic chromium compounds have never been observed on diffraction patterns. In one or two cases of treatment of gut with very concentrated chromicizing solutions, a few single spots due to isolated single crystal grains have appeared, but these cannot be identified. Crystalline layers of dichromate or of chromic oxide, the reduction product, have not been found. The evidence, therefore, is that a non-crystalline addition complex is formed the structural backbone of which is essentially the same as the protein. Chromium is unquestionably present since it may be found by microchemical tests. Some ligatures were heated at temperatures just below charring for as long as 48 hours, which would be sufficient for dehydration of any colloidal hydroxides. Even after this treatment no evidence of crystalline oxides is found.

7. The vulcanization of rubber seems to be quite analogous to the chromicizing of catgut. No evidence of crystalline sulphur is ever found up to a certain limit, and the appearance of a fiber pattern on stretching is iden-

tical with that of unvulcanized rubber except for one change; the crystal interferences are actually narrower, indicating a larger colloidal particle size as though the sulphur had bridged initial units together. Exactly this same observation is made for chromicized gut. The arcs and spots on the crystal rings are measurably narrower, so that chromium in some form bridges protein particles together into larger units. This X-ray observation is also consistent with greater resistance to swelling and absorption.

## BIBLIOGRAPHY


BERGMANN, M., and JACOBI, B. Kolloid-Ztschr., 1929, xlix, 46.

CLARK, G. L., BUCHER, C. S., and LORENZ, O. Radiology, 1931, xvii, 482.

CLARK, G. L., and LANYON, C. Applied X-rays. 1st ed., p. 194. New York: McGraw-Hill Book Company, 1927.

CLARK, G. L., and SISSON, W. A. Industrial and Engineering Chemistry, Analytical Edition, 1933, v, 296.

GURLT, E. Geschichte der Chirurgie und ihrer Ausuebung. 3 vols. Berlin, 1898.

GREIFENBERGER, W. Historish-kritische Darstellung der Lehre von der Unterbindung der Blutgefasse. Deutsche Ztschr. f. Chir., 1882, xvi, 111–148, 285–329.

HERMANN, K., GERNGROSS, O., and ABITZ, W. Ztschr. f. phys. Chemie, 1930, x, 371.

HERZOG, R. O. Helvetica Chimica Acta, 1928, xi, 529; Berichte den deutschen, Chemischen Gesellschaft, 1925, lviii, 2228.

KATZ, J. R., and GERNGROSS, O. Naturwissenschaften, 1925, xiii, 900; Kolloid Ztschr., 1926, xxxix, 181.

LISTER, J. Observations on ligatures of arteries on the antiseptic system. Lancet, 1869, i, 451.

MEYER, K., and MARK. Biochem. Ztschr., 1929, ccxiv, 253.

PARÉ, A. Oevres completes, par J. F. Malgaigne, 3 vols. Paris, 1840.

PHYSICK, P. S. Eclect. Repert. & Anal. Rev., vol. vi, pp. 389–390. Philadelphia, 1816.

PORTA, L. Delle alterazioni patologiche delle arterie per la legatura e la torsione, esperienze ed osservazioni, p. 40. Milani.

TRILLAT, J. J. J. de chim. phys., 1932, xxix, 1.


Acknowledgment must be made to the Curity Suture Laboratories who provided the funds for this work in such a fundamentally important field. Research in the realm of protein structure is only beginning. But even in this beginning the medical scientist cannot but feel a sense of added indebtedness to X-rays, so indispensable in diagnosis and therapy, and now presented in a third great field of application. With X-rays one can see far beyond the microscope down to the ultimate arrangement of atoms and molecules even in living tissues and find there the real secret of constitution and practical behavior of material things.

# THE PREVENTION OF PERSISTENT AND RECURRENT HYPERTHYROIDISM

## Based on a Study of Seven Hundred Sixty-Nine Cases of Exophthalmic Goiter

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Jackson Clinic

THE literature contains some twenty articles relating to recurrent or persistent hyperthyroidism, but none pertaining to the particular phase to be discussed. Recurrence in toxic adenomata is of such rarity as scarcely to merit discussion. There have been several excellent dissertations on recurrent exophthalmic goiter, the most important being those by Drs. Clute, Lahey, Pemberton, and Thompson. The paper by Thompson and his associates, A. E. Morris and P. K. Thompson, is most instructive and comprehensive and should be read by anyone interested in the subject of hyperthyroidism. In this short treatise it is impossible to discuss the opinions of these authors, none of whom was especially concerned with the problem of prevention. Lahey, Clute, and Thompson were really dealing with persistent rather than recurrent hyperthyroidism, since in their analyses the latter condition was rarely observed.

Lahey and Clute reported 24 cases of primary hyperthyroidism in which the patients returned for secondary operation. In 19 the metabolic rate never returned to normal after the first operation; consequently they were cases of persistent rather than recurrent hyperthyroidism. Of the latter group, they reported only 5 cases. Likewise Thompson et al in reviewing the cases operated on at the Massachusetts General Hospital during the years 1923 to 1928 found that while 37 of 190 cases, or 19.5 per cent, showed definite clinical evidence of postoperative thyrotoxicosis, in only two instances was there a true recurrence.

On the other hand, Pemberton recently estimated the incidence of postoperative thyrotoxicosis following subtotal thyroidectomy for exophthalmic goiter at the Mayo Clinic as "certainly not more than 5 per cent." Frazier and Mosser followed up a series of 100 cases of exophthalmic goiter in 1928 and found that 1 per cent had persistent hyperthyroidism and 4 per cent had recurrent hyperthyroidism. In 1920, Mason found that a second operation was necessary in 12 per cent of a series of 42 cases of exophthalmic goiter. Undoubtedly the advent of iodine would considerably alter these figures.

A review of the literature as shown by Thompson indicates that the incidence of thyrotoxicosis after subtotal thyroidectomy for exophthalmic goiter ranges from 0.25 to 25 per cent, many of the estimates falling in the vicinity of from 5 to 7 per cent. The value of these statistics depends upon the accuracy of the follow-up, the number of personal examinations, and the interval elapsing since the operation—points emphasized by Pemberton.

Patients failing to reply to a questionnaire or reported lost may have gone elsewhere for a second operation. Surgeons may hesitate to discuss unsuccessful results but since the technique of thyroidectomy has become standardized there is no reason why this subject should not be frankly considered. Any experienced thyroid surgeon knows that complications occur in spite of the greatest care and attention to details. Regardless of a correct diagnosis, a well planned pre-operative and postoperative regimen, and a technically perfect thyroidectomy, hyperthyroidism may return just as cancer does, 1, 5, or even 20 years later. Occasionally a second or third operation may not be successful. Once I performed the fourth thyroidectomy on a patient who had previously been operated on by two of our leading thyroid surgeons.

Fortunately, however, these cases are the exception and considering the fact that 5,000 or more thyroidectomies are performed each year for exophthalmic goiter, the number of recurrences is small; certainly not in excess of 10 per cent, although this figure might be

TABLE I.—AVERAGES OF ALL CASES OF PERSISTENT EXOPHTHALMIC GOITER OBSERVED AT JACKSON CLINIC 1922–1932

| | |
|---|---|
| No. cases | 19 |
| Average age | 35 |
| Sex | M, 7; F, 12 |
| Duration symptoms | 5.7 months |
| Tonsils | 8 septic; 6 no record |
| Original weight loss | 24 pounds |
| B.M.R. on admission | +48.5 per cent |
| B.M.R. on return | +51.3 per cent |
| B.M.R. on discharge | +8.1 per cent |
| Weight gain | 21 pounds |

B.M.R., basal metabolic rate

TABLE II.—PERSISTENT CASES OF EXOPHTHALMIC GOITER CURED WITHOUT OPERATION

| | |
|---|---|
| No. cases | 3 |
| Average age | 37.2 |
| Sex | M, 1; F, 2 |
| Duration symptoms | 6.5 months |
| Tonsils | septic, 1 |
| Weight loss | 19 pounds |
| B.M.R. on admission | +45 per cent |
| B.M.R. on readmission | +23.6 per cent on iodine |
| B.M.R. on discharge | +13.6 per cent no iodine |
| Weight gain | 13.3 pounds |

exceeded if all cases of persistent hyperthyroidism were included.

Before continuing I shall define the terms "recurrent" and "persistent" hyperthyroidism. The recurrent case is any case of exophthalmic goiter in which iodine is not given but the patient shows a normal metabolic rate with complete abatement of symptoms for 3 months or more following subtotal thyroidectomy and then develops a recurrence with signs and symptoms of hyperthyroidism together with an increased basal metabolic rate. Persistent hyperthyroidism means a continuation of the clinical signs and symptoms of exophthalmic goiter together with an increased metabolic rate after the withdrawal of iodine for a period of 6 months or longer following subtotal thyroidectomy—the condition being the result of the removal of an insufficient amount of thyroid gland.

I reiterate that hyperthyroidism recurring after thyroidectomy for toxic adenoma is so rare as to obviate consideration; nor are we concerned with that type of case in which symptoms of a permanently damaged cardiovascular system persist after a too long delayed thyroidectomy. Every surgeon doing thyroid surgery is familiar with the neglected case of hyperthyroidism that improves following thyroidectomy only to die a cardiac death a few years later.

At the Jackson Clinic between 1922 and 1932, 722 operations including ligations, lobectomies, and thyroidectomies have been performed on 769 patients with exophthalmic goiter. During this period of 10 years a total of 22 patients were operated upon for persistence of the disease following thyroidectomy; 5 of these had had the primary operation elsewhere and 17 underwent their first operation at the Clinic. Of the 22 patients with persistent hyperthyroidism, 3 have been restored to normal health without surgery by methods to be discussed. With the exception of one case now under observation, these patients have remained well 6 months or longer without iodine and may be considered as well. That does not mean that at any time in the future the disease may not recur, a possibility in every case of exophthalmic goiter.

It is contrary to the experience of Lahey and Clute who state that in no case of persistent or recurrent hyperthyroidism in their experience has the use of iodine resulted in a cure. I have been interested in this subject for several years and have reported two cases of this type restored to normal health. In the majority of patients, however, it is necessary to remove more thyroid tissue.

In 4 instances a third thyroidectomy was required before the patient was relieved of hyperthyroidism; 2 of these were Clinic cases.

There were 36 cases of recurrent hyperthyroidism, in 25 of which the patients had undergone thyroid operations by other surgeons. Of these 16 probably had only a lobectomy at their first operation, since this was then the operation of choice. Two patients have refused surgery and their symptoms are partially controlled by iodine, but a prolonged low grade hyperthyroidism is beginning to effect cardiac damage.

Just as we must start the prevention of simple goiter by administering iodine during pregnancy, so must we begin at the earliest opportunity to prevent the development of persistent and recurrent hyperthyroidism. The surgeon may be blamed in many instances

TABLE III.—RECURRENT EXOPHTHALMIC GOITER PROBABLY HAD LOBECTOMY ELSEWHERE

| | |
|---|---|
| No. cases | 14 |
| Average age | 40 |
| Sex | M, 2; F, 12 |
| Duration symptoms | 10.2 months |
| Tonsils | Septic, 2; no record, 5, 12 |
| Weight loss | 23.2 pounds |
| B.M.R. on admission | +34.9 per cent |
| B.M.R. on discharge | +2.6 per cent |
| Weight gain | 19.8 pounds |

TABLE IV.—AVERAGES OF ALL CASES OF RECURRENT EXOPHTHALMIC GOITER OBSERVED AT JACKSON CLINIC 1922–1932

| | |
|---|---|
| No. cases | 32 |
| Average age | 39 |
| Sex | M, 7; F, 25 |
| Duration symptoms | 9.3 months |
| Tonsils | Septic, 14; no record, 18 |
| Weight loss | 24.6 pounds |
| B.M.R. on admission | +39.4 per cent |
| B.M.R. on discharge | +3.7 per cent |
| Weight gain | 21.9 pounds |

for a persistence of hyperthyroidism because of a failure to remove sufficient thyroid tissue, yet he cannot always be held responsible. Doing the same operation day after day, it is unreasonable to believe that his technique might so vary as to fail to remove enough gland in 1 out of every 10 or 20 cases. More likely the tremendous force that is driving the gland continues to carry on in spite of a thyroidectomy that would usually be adequate. One learns to anticipate trouble in the extremely acute vascular type and in these as much thyroid tissue as possible should be removed without causing hypothyroidism, or injuring the parathyroid glands or the recurrent laryngeal nerves. I agree with Pemberton when he says, "Today these are far too excessive a price to be paid for the removal of goiter." One case of postoperative myxœdema, and that an unusual one in which 2 years following the removal of a non-toxic adenoma it was necessary to reoperate for an exophthalmic goiter, has occurred in my experience. Since 1925 no cases of tetany or of nerve injury have resulted. Probably my percentage of persistent hyperthyroidism and recurrence is higher than it should be but, so far as I know, every case that has permitted treatment or reoperation is well today.

If postoperative thyrotoxicosis is to be successfully combated, certain facts must be impressed upon the patients from the first day. They must realize that a thyroidectomy is not the same as an appendectomy. Written rules to follow both before and after operation should be given patients because in their nervous, high strung condition, most advice goes in one ear and out the other. To restore their health is not sufficient; they must be kept well to prevent a recurrence. One must use tact, of course, and not frighten already apprehensive patients. They should be assured that with co-operation, health will be restored.

Because of the many probable etiological factors in exophthalmic goiter, every patient must be individually considered and advised. In one, infections such as tonsillitis and influenza appear to be important, in another prolonged mental and physical strain such as the care of a sick relative or occupational stress as experienced by stenographers, telephone operators, etc. Pregnancy and menopause may initiate hyperthyroidism; likewise shock, worry, iodine deficiency, and a nervous constitution. The increased incidence of hyperthyroidism that followed the influenza epidemics of 1918 to 1921 is well remembered. Septic tonsils appear to be such a definite factor in many of my patients that for several years I have advised tonsillectomy 2 or 3 months after thyroidectomy when indicated.

If occupation is a possible etiological factor, a change should be advised, and a lighter outdoor form suggested. There should be relief from the burden of too many duties either at home or in the office.

The patient who fails to gain weight following thyroidectomy probably has a persistent hyperthyroidism. The importance of gaining weight within the first 6 weeks following operation must be emphasized. A gain of 10 pounds the first month is the minimum; specific instructions should be given regarding a high caloric diet, regular weighing, etc. All stimulants and particularly coffee should be permanently dispensed with.

Persistent and recurrent hyperthyroidism is especially apt to occur in young people who have a tendency to overestimate their abili-

ties. They should be cautioned against loss of sleep and rest. The relief of part or all school work is advisable.

Iodine therapy is of the utmost importance. Thirty drops of Lugol's solution is given daily when the patient leaves the hospital. This amount is decreased to 5 drops three times a day after 4 weeks and this dosage is continued for 6 months or longer as indicated.

If hyperthyroidism shows a tendency to persist or recur, it may be possible to alleviate the symptoms entirely and effect a cure by the use of iodine, a high caloric diet, rest, and the removal of septic tonsils, provided the patient is seen in sufficient time.

If, after several months trial, the thyroid enlargement does not diminish, if the metabolism is elevated and the patient loses weight when iodine is withdrawn, then the remaining excessive tissue should be removed. If this is not done, the prolonged effect of even a low grade hyperthyroidism will be manifested by cardiac arrhythmia, myocarditis, and hypertension.

In conclusion, I wish to discuss briefly the most important single factor, the use of iodine excepted, in the prevention of persistent and recurring hyperthyroidism. By the use of the radio-electrical surgical knife during the past 3 years, I have practically eliminated these problems. Attention has been called to the use of this method by Mock, Bartlett, Tinker, and myself[1]. With the swift cutting radio knife it is possible to remove all but a shell of the diseased thyroid gland, without endangering the laryngeal nerves or the parathyroid glands. It is impossible to perform as complete and thorough an operation with the scalpel, and when occasionally compelled to forsake the radio knife because it is unavailable, I feel that I have gone back 5 years in surgery.

When the gland has been completely peeled out as one would an orange, it is possible with the high frequency or coagulating current to sear over the entire inner surface coagulating any bleeding points and by producing fibrosis destroy all but the external surface. With such an extensive operation and recovery so rapid, postoperative myxœdema might be expected, but no instance of this has occurred; nor is postoperative drainage a factor, since we seldom use a drain.

Experience is required just as with any other new procedure and important vessels such as the superior or inferior thyroid arteries or the lateral veins should not be coagulated. With practice it is possible to perform thyroidectomy far more quickly, more thoroughly, with fewer complications, and with better end results by this method.

The incidence of persistent and recurrent hyperthyroidism at the Jackson Clinic has been reduced from 5.5 per cent in 1925–1928 to 1 per cent in 1930–1933 by this method. It is possible that more recurrences will develop in time, but I am satisfied that electrosurgery has largely eliminated this most serious indictment of the surgical treatment of exophthalmic goiter.

[1]Mock. J. Am. M. Ass.; Bartlett. Surg., Gynec. & Obst.; Tinker. Am. Surg.

SUMMARY

An analysis is presented of 22 cases of persistent and of 36 cases of recurrent hyperthyroidism based on a study of 769 patients with exophthalmic goiter observed at the Jackson Clinic 1922–1932. During this period there were 722 operations performed on patients with exophthalmic goiter.

Of the 22 patients with persistent hyperthyroidism, 17, or 77.27 per cent, had previously undergone a subtotal thyroidectomy at the clinic. Three of the 17 cases were restored to normal health without further surgery. Iodine, rest, a high caloric diet, the elimination of worry, strain, and focal infection were important factors.

A second thyroidectomy was performed on 12 of the persistent cases and a third on 2 of them. At present all are well with a normal basal metabolic rate 6 months after withdrawal of iodine. Two cases have refused operation, and while their symptoms are partially controlled by iodine there is evidence of increasing cardiac damage.

Of the 36 cases of recurrent hyperthyroidism, 11 or 30 per cent had previously undergone operation at the Clinic. The primary operation in 16 of the 36 recurrent cases operated upon elsewhere was probably only

a lobectomy. Twenty-three of the 58 cases of persistent and recurrent hyperthyroidism had septic tonsils at the time of thyroidectomy. Tonsillectomy is advised within 3 months following thyroidectomy in all cases of exophthalmic goiter with septic tonsils.

The basal metabolic rate of the 22 cases of persistent hyperthyroidism averaged plus 48.5 per cent on admittance and plus 8.1 per cent on final discharge.

The average weight loss was 24 pounds before thyroidectomy. The average weight gain was 21.5 pounds on discharge.

The basal metabolic rate of the 36 cases of recurrent hyperthyroidism averaged plus 39.4 per cent on admittance. The basal metabolic rate of the 11 cases having their primary thyroidectomy at the Clinic was plus 37 per cent. On readmission the basal metabolic rate averaged plus 48 per cent, and on final discharge plus 6 per cent. The average weight loss of the 36 cases previous to the second thyroidectomy was 24.6 pounds and the average weight gain on discharge was 21.9 pounds.

Of the 22 cases of persistent hyperthyroidism, there were 12 females and 7 males averaging 35 years of age.

Twenty-five of the 36 cases of recurrent hyperthyroidism were females and 7 were males averaging 32 years of age.

In the prevention of persistent or recurrent hyperthyroidism, the following factors are stressed:

The use of iodine for 6 months or longer following thyroidectomy. Special care of the acute fulminating type with the large vascular gland.

Elimination of focal infection, worry, strain, and occupational factors.

The importance of weight gain, especially in the first 6 weeks.

Permanent abstinence from coffee and other stimulants.

The use of the radio electrosurgical knife has largely eliminated the factors of persistent and recurrent hyperthyroidism. Their incidence has been reduced from 5.5 per cent in 1925–1928 to 1 per cent during 1930–1933 at the Jackson Clinic.

REFERENCES

1. Clute, H. M. Hyperthyroidism persisting after thyroidectomy: the necessity for postoperative examination in toxic goiters. Surg. Clin. N. America, 1926, vi, 691.
2. Else, J. E. Prevention of recurrent goiter. Surg. Clin. N. America, 1928, viii, 1375.
3. Frazier, C. H., and Mosser, W. B. End-results from the surgical treatment of hyperthyroidism. J. Am. M. Ass., 1928, xc, 657.
4. Lahey, F. H., and Clute, H. M. Persistent and recurrent hyperthyroidism. Ann. Surg., 1926, lxxxiii, 199.
5. Mason, J. T. Mistakes in one hundred thyroidectomies, with description of a new method of thyroid cauterization in treating exophthalmic goiter. J. Am. M. Ass., 1920, lxxv, 160.
6. Pemberton, J. deJ. Recurring exophthalmic goiter: its relation to the amount of tissue preserved in operation on the thyroid gland. J. Am. M. Ass., 1930, xciv, 1483.
7. Thompson, W. O., Morris, A. E., and Thompson, P. K. Thyrotoxicosis following subtotal thyroidectomy for exophthalmic goiter. Arch. Int. Med., 1930, xlvi, 946–978.

# RELAXATION OF THE PELVIC JOINTS IN PREGNANCY[1]

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KNOWLEDGE of the behavior of the pelvic joints in pregnant women is of interest not only in relation to the clinical management of the puerperal state and of its complications, but also because of the light it may shed upon a type of physiological process affecting certain articulations about which little is known. That relaxation of the pelvic joints in pregnancy may also have more remote consequences is suggested by the fact that not infrequently chronic backache in women is found to have originated following parturition. One may recall that the work of Goldthwait and Osgood establishing the entity and symptomatology of disturbances of the sacro-iliac joints owed its origin in part to observation of those joints during pregnancy.

The purpose of this paper is to make a preliminary report of the results of studies still in progress at the Boston Lying-in Hospital centering around the general subject of pelvic joint relaxation in pregnancy.

## REVIEW OF THE LITERATURE

Although it is full of interest, it is unnecessary to enter into a review of the early history of the subject, since this has been fully covered in articles by Snelling, 1870; Cantin, 1899; Lynch, 1920; Boland, 1932; and Heyman and Lundquist, 1932. A great controversy was engaged from earliest times over the Hippocratic theory of "disjunctio pelvica." Contributions were made to it by numerous authors including Vesalius, Severin Pinean, Ambroise Paré, Albinus of Leyden, William Hunter, Velpeau, Jacquemier, Baudelocque, Lenoir, Luschka, and many others. Their views differed markedly, some believing that pelvic joint relaxation was a normal and constant phenomena, others that it was exceptional and pathological. During the last century most authors have accepted the view that the pelvic joints softened and became relaxed during the pregnant state, but no accurate studies have been made of the frequency and degree of separation until the recent article by Heyman and Lundquist, 1932, which appeared subsequent to the beginning of our own studies.

Interesting parallels have been found among various mammals. In 1812, LeGallois described the mechanism in the female guinea pig which permitted the delivery of a fetus with a head of an average diameter of 20 millimeters from a pelvic outlet with an average normal diameter of 11 millimeters. Three weeks before term the pubic ligaments became thick and malleable and allowed the symphysis to separate a distance of 1 to 2 fingers' breadth. Shrinkage began immediately following delivery, and within a few days the symphysis receded to normal width and consistency. Similar processes have been described in the seal (Barlow), the pocket gopher (Hisaw), and the cow (Knox). In the latter animal the relaxation chiefly affects the sacro-iliac joints.

There has been considerable discussion of the mechanism by which relaxation in women is brought about. Some writers observed that the joints became swollen to the extent of a third or even one-half greater than their normal volume. Stolts considered this to be definitely pathological and that it served no physiological purpose. Luschka (18) believed that the symphysis pubis was an incomplete joint, and that during pregnancy it became distended by a copious secretion of synovial fluid. Snelling concluded that a certain degree of relaxation occurred as a purely physiological mechanism, but that beyond a certain limit the process became pathological in that the ligaments became saturated with serum, lost their firm and resilient qualities, and the amount of synovial fluid was greatly increased. This initiated a train of symptoms which was due to the inability of the pelvis in its relaxed state to sustain the general body weight.

[1] Read before the American Orthopaedic Association, Washington, D. C., May, 1933.

Cantin, in 1899, reported that he found tactile evidence of relaxation of the symphysis pubis in 408 out of 500 pregnant women examined, and that the degree of separation varied from 1 to 3 millimeters. He was able to demonstrate mobility at the symphysis in all but 2 per cent. His studies were made without the aid of roentgen examination. He stated that of all the ills of pregnant women there was none more common or more frequently overlooked than relaxation of the pelvic joints.

Heyman and Lundquist made a study of the width of the symphysis pubis in pregnant and non-pregnant individuals using an accurate method of roentgenological measurement. They reported a large series of measurements as follows:

Control series: (I) 70 normal nulliparæ aged 19 to 42 years of which 80 per cent showed a width of the pubic gap of 5 millimeters or less; (II) 392 non-pregnant women aged 5 to 80 years of which 84 per cent had measurements of 5 millimeters or less; (III) 368 males aged 5 to 80 years of which 90 per cent showed measurements of 5 millimeters or less. (In each of these three groups there were only a few individuals who showed measurements of over 6 millimeters); (IV) 74 women who were pregnant aged 19 to 39 years of which 48 were primiparæ and 26 multiparæ.

They noted an increase in width of symphysis of usually 1 to 2 millimeters with a maximum of 4 millimeters. The average width was between 7 and 8 millimeters and the maximum 12 millimeters.

They concluded that an increase in the width of the symphysis pubis occurred in all pregnant women, that the increase antepartum was not as great as the decrease postpartum, but explained this as due to the fact that no measurements were made before the fifth month of pregnancy. They did not believe that any increase took place in the last 2 months of pregnancy or during the course of labor. The greatest increase was observed to occur between the fifth and seventh months of the antepartum period. They considered that the widening of the symphysis was brought about by an active biological process, begun in the early stages of pregnancy and tending together with similar changes affecting the sacro-iliac joints to increase the roominess of the pelvis.

In respect to the instances of wide pubic separation that have been occasionally encountered these have generally been ascribed to the effects of trauma either preceding or accompanying parturition. A number of authors have written on this subject and published case reports. The symptoms due to pelvic instability have been described. Lynch, in 1920, made a roentgenological examination of pelvic joints during labor without reaching any definite conclusion. Only one of the women showed marked widening of the symphysis with a return to normal when examined 15 months later. He noted constant widening of the sacro-iliac joint spaces. Brehm and Weirauch, in 1928, reported 54 cases of pubic separation. They attempted to establish normal and abnormal degrees of separation. They stated that patients with a gap of under 8 millimeters or less showed no symptoms of pelvic instability; those with a gap of from 9 to 20 millimeters had slight symptoms, and those with measurements of over 20 millimeters had marked symptoms. Lieh-Chung Wu, in 1930, reported 3 cases and attributed the condition to mechanical causes or instrumental delivery, and also questioned the presence of weakness of the pelvic ligaments of congenital origin.

Reis, Baer, Arens, and Stewart, in 1932, were able to collect from the literature reports of 62 cases with pubic separation to which they added 5 of their own. They did not believe that any characteristic changes occurred at the symphysis as a result of pregnancy and were unable to demonstrate in 80 consecutive cases by roentgenological examination any difference in the appearance of the pubic gap from that of normal non-pregnant women. They attributed all instances of pubic separation to mechanical causes, to marked intensity of uterine contraction, rapidity of labor, and to disproportion between the size of the fetus and of the pelvic outlet.

Numerous articles have also been published dealing with the gross and microscopic anatomical changes in the symphysis pubis, the most complete of which is that of Putschar.

He described the appearance of the joint at different ages and in pregnant and non-pregnant individuals. He pointed out the constancy of the cleft formation both in males and females and attributed the changes during pregnancy to the extensive loss of the interosseous cartilage and the development of a genuine joint.

### PLAN OF STUDY

Our own attention was first directed toward the need for study of the changes in the pelvic joints during pregnancy by the finding of wide separation of the pubis in several women who were examined 1 to 2 weeks following delivery because of the development of painful symptoms. We accepted the usual explanation of trauma during delivery to account for the condition. Shortly afterward, however, one of us observed a similar condition in a patient who had only reached the sixth month of pregnancy, and in whom we were able to exclude any possible relationship to trauma. Plans for a co-operative orthopedic and obstetrical investigation of the condition were then made.

A review was made of a number of X-ray films of the pelvis made during pregnancy that were found in the files of the Roentgen Department. This showed that little measurable change could be demonstrated in the sacro-iliac joints, but that on the other hand marked changes could be noted at the symphysis pubis. This determined our plan to use the width of the symphysis pubis as an index of relaxation of the pelvic joints and to compare the width in pregnant women with that of non-pregnant controls. Various side lines of interest have developed during the study, and it is our hope that we may be able to follow these up and make additional reports of the results later.

### ANATOMY OF THE SYMPHYSIS PUBIS

It is stated in Cunningham's *Text Book of Anatomy* that the symphysis pubis is an amphiarthrosis and that each pubic bone is covered by a layer of hyaline cartilage. Between these two hyaline plates there is interposed a disk of fibrocartilage in the interior of which there is usually a vertical anteroposterior cleft. This cavity is placed nearer the posterior than the anterior aspect of the joint, and does not appear until between the seventh and tenth years of life. It is not lined by any synovial stratum and is supposed to result from the breaking down of the interpubic laminæ. There are four ligaments, the anterior, the posterior, the superior, and the arcuate. The anterior ligament is of considerable thickness and strength, its fibers forming an interlaced decussation. The posterior ligament is very weak and consists of scattered fibers running transversely. The superior ligament is also weak, and is made up of transverse fibers passing between the two pubic crests. The arcuate ligament is of considerable strength and occupies the arch of the pubis. It gives roundness to the pubic arch and forms part of the boundary of the inferior aperture of the pelvis.

At birth the rami of the pubis are well ossified, but the descending rami are joined to the ascending rami of the ischium by a band of cartilage which becomes completely ossified at about the eighth year or earlier. The suture line may be visible as an indentation up to the eighteenth year. The symphyseal space is occupied by a solid mass of cartilage and is much wider than in adult life. Gradually this is narrowed by advancing ossification of the central margins of the pubic bones until it is reduced to its fixed adult size at about the twentieth year. Actually ossification may continue up to the twenty-fifth year as shown by our roentgenologic measurements which were always wider in the third than in the later decades due to the inclusion of a few cases in which the development was still incomplete.

### METHODS OF ROENTGENOLOGICAL MEASUREMENT

It first became necessary to find out what degree of error existed in making direct measurements of the width of the symphysis pubis on flat X-ray films and whether a special technique would have to be employed. We made use of the method of stereoroentgenometry described by Clayton Johnson to check up on this point. The technique of this method has been fully described and will not be repeated here. It is sufficient to state that

TABLE I.—CONTROL SERIES, NORMAL NON-PREGNANT FEMALES

X-ray measurements of symphysis in 123 individuals

| Width of symphysis in mm. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total | Averages mm. |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | Nulliparæ | | | | | | | | | |
| 21–30 | 0 | 0 | 3 | 14 | 4 | 1 | 0 | 0 | 22 | 4.1 |
| 31–40 | 0 | 0 | 2 | 5 | 1 | 1 | 0 | 0 | 9 | 4.0 |
| 41–50 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | |
| 51–60 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | |
| Totals | 0 | 0 | 7 | 19 | 5 | 2 | 0 | 0 | 33 | 4.09 |
| | Primiparæ | | | | | | | | | |
| 21–30 | 0 | 1 | 0 | 2 | 4 | 0 | 0 | 0 | 7 | 4.3 |
| 31–40 | 0 | 0 | 2 | 6 | 3 | 0 | 0 | 0 | 11 | 4.09 |
| 41–50 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | |
| 51–60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Totals | 0 | 2 | 2 | 8 | 7 | 1 | 0 | 0 | 20 | 4.15 |
| | Multiparæ | | | | | | | | | |
| 21–30 | 0 | 0 | 0 | 2 | 3 | 1 | 2 | 0 | 8 | 5.4 |
| 31–40 | 1 | 0 | 2 | 11 | 13 | 6 | 0 | 0 | 33 | 4.6 |
| 41–50 | 0 | 1 | 7 | 6 | 8 | 2 | 1 | 1 | 26 | 4.4 |
| 51–60 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | |
| 61–70 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | |
| Totals | 1 | 1 | 10 | 19 | 26 | 9 | 3 | 1 | 70 | 4.6 |

it is a method of accurately localizing and determining the dimensions of any radio-opaque substance in the body from its stereoscopic roentgenograms.

Measurements of the width of the symphysis pubis were made by this method in 25 pregnant women who showed varying amounts of separation. Comparison was then made between these measurements and those obtained by direct measurement on the film of the distance between the pubic bones. The variation in all cases was found to be trifling, never amounting to more than 1 millimeter, and for practical purposes, and especially for comparison of relative changes, it seemed to us that the simpler method of direct measurement could be accepted as reasonably accurate. A fixed distance between tube target and film is of course necessary, and for this purpose we routinely employed a distance of 30 inches.

An opportunity for error by this method lies in irregularity of the pubic bones, more marked in some cases than in others, and also in the varying obliquity of the pelvic axis. Since the pregnant woman finds it difficult to lie in the ventral position, roentgenograms of the symphysis must be made with the patient lying on her back. In most of the patients the axis of the pelvic canal is oblique from above downward and backward, but there results a fair anteroposterior projection of the pubic bones upon the film and the width of the symphysis can be readily determined. In other cases the pelvis is more tipped and the axis of the pelvic canal is almost horizontal so that the projection of the pubic bones upon the film is in the vertical diameter instead of anteroposterior. In these cases there is always a large amount of superimposed shadow which makes it difficult to determine accurately the limits of the pubic gap, but the

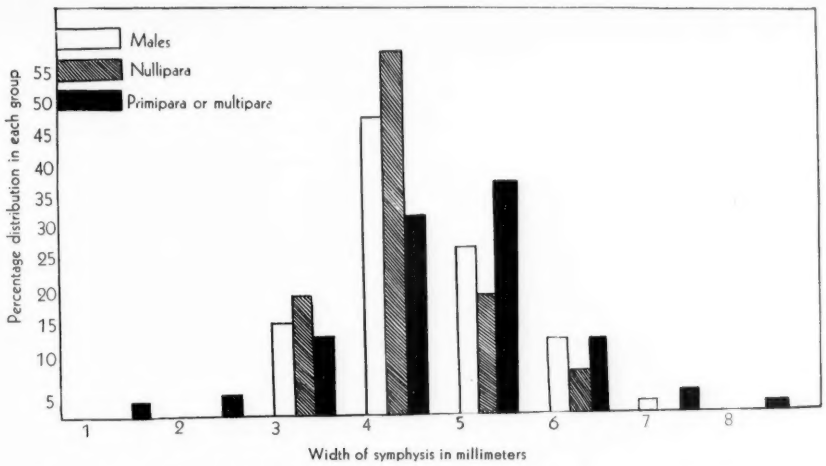



Fig. 1. Composite table showing comparative symphyseal measurements in groups of males, nulliparæ, and non-pregnant primiparous or multiparous women.

effect of this is always to narrow and never to widen the symphysis so that measurements by this method are never exaggerated. We marked the edges of the two pubic bones with a pencil at the narrowest diameter of the symphyseal space and measured between these points.

### NORMAL CONTROL MEASUREMENTS

1. *Females.* In order to establish what constituted the normal variation of symphyseal width in non-pregnant women a series of measurements were made from a group of pelvic X-ray films that had been made for gynecological diagnostic purposes. In this way measurements were obtained of 123 women, comprising 33 nulliparæ, 20 uniparæ, and 70 multiparæ. The results are shown in Table I.

From this it will be seen that there was relatively little difference between the width of the symphysis of the various groups, the average for the nulliparæ being 4.09 millimeters, for the uniparæ 4.15 millimeters, and for the multiparæ 4.6 millimeters. The measurements are shown graphically in Figure 1 and study of this chart shows better than the table a definite tendency toward greater width of the symphysis in the multiparous women than in the nulliparous. In the former the peak is at 5 millimeters, while in the latter it is at 4 millimeters. It will also be noted that there is distinctly greater variation in the symphyseal measurements of the women who have borne children. In the nulliparæ the measurements varied from 3 to 6 millimeters inclusively, while in the multiparæ the variation was from 1 to 8 millimeters, inclusively.

There was also noted a difference between the appearance of the symphysis in the nulliparous and multiparous women. In the former the outline of the symphyseal margins of the pubic bones was smooth with only a thin cortical layer of increased density. In the multiparous women there appeared to be a definite tendency to greater irregularity of the pubic margins of the symphysis with greater unevenness of the cortical outline and occasionally small round areas of decreased density suggestive of cyst formation. It was frequently possible to tell from the X-ray appearance of the symphysis whether or not the woman had previously borne children.

The difference in the measurements and appearance of the symphysis would seem to indicate that pregnancy is usually followed by changes at the symphysis pubis.

Age seemed to have very little influence upon the width of the symphysis, the averages for the different decades being approxi-

Fig. 2. X-ray picture of the pelvis of a multiparous woman. The irregularity of the symphysis pubis is to be noted.

Fig. 3. X-ray picture of the pelvis of a multiparous woman. Note the apparent cystic formation of the margin of the symphysis pubis.

mately the same, although the number of individuals in the decades above 40 was too small to make the figures reliable on that point. The average width in the 21 to 30 age group is slightly larger because of the inclusion of a few individuals in whom osseous development had not as yet reached the completed stage.

2. *Males.* It also seemed of interest for comparative purposes to study the symphysis pubis in males. A group of pelvic films were examined that had been made for the purpose of genito-urinary diagnosis in 71 individuals. The results are shown in Table II and they have also been included in the graph (Fig. 1) for comparison with the females. As far as the width of the symphysis was concerned there was no difference between the group of nulliparæ and the males. The average width for the entire group was 4.4 millimeters and the variation was from 3 to 6 millimeters with the exception of one individual who measured 7 millimeters. The roentgen appearance of the male symphysis was also similar to that of the nulliparæ except for the well-known masculine and feminine characteristics of the pelvis itself. The pubic margins were generally smooth and straight. Although there was no difference in the average width between the various decades, there were noted slight productive or hypertrophic changes in some of the individuals of advanced years (Fig. 4, A). In one man of 72 there was noted complete bony bridging at the superior margin of the symphysis, but details of the patient's history were lacking (Fig. 4, B).

TABLE II.—CONTROL SERIES—NORMAL MALES

X-ray measurements of symphysis in 71 males

| Age | Width of symphysis in millimeters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total | Averages mm. |
| 21–30 | 0 | 0 | 0 | 4 | 2 | 1 | 0 | 0 | 7 | 4.5 |
| 31–40 | 0 | 0 | 2 | 6 | 3 | 0 | 0 | 0 | 11 | 4.0 |
| 41–50 | 0 | 0 | 2 | 6 | 2 | 2 | 1 | 0 | 13 | 4.5 |
| 51–60 | 0 | 0 | 2 | 6 | 2 | 3 | 0 | 0 | 13 | 4.5 |
| 61–70 | 0 | 0 | 3 | 10 | 5 | 1 | 0 | 0 | 19 | 4.2 |
| 71–80 | 0 | 0 | 1 | 1 | 4 | 1 | 0 | 0 | 7 | 4.7 |
| 81–90 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | |
| Totals | 0 | 0 | 10 | 33 | 20 | 8 | 1 | 0 | 71 | 4.4 |

Fig. 4. A. Typical male pelvis. The line of the symphysis pubis is straight. B. Male pelvis (age 72). A straight symphysis showing also complete bony bridging.

Fig. 4, B.

The average measurements of both the women and the men corresponded closely with those reported by Heyman and Lundquist.

STUDY OF PREGNANT WOMEN

1. *First group.* A series of measurements were made of a group of X-ray films of the pelvis that had been made in the last 2 months of pregnancy for the study of fetal measurements. The group comprised 111 individuals chosen without any selection and they were not differentiated in respect to parity, although the great majority were multiparæ. The measurements of the symphysis are shown in Table III.

These showed a very definite increase in the width of the symphysis on the whole and a very marked variation between the individuals. The average width was 7.7 millimeters, an increase of 3 millimeters over the average width of a similar non-pregnant group (4.6 millimeters). The averages for the

TABLE III.—MEASUREMENTS OF PUBIC WIDTH IN 111 PREGNANT MULTIPARÆ—IN LAST TWO MONTHS OF PREGNANCY

| Age | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Total | Average—mm. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18–20 | | | | 1 | 1 | 1 | | 2 | | | | | | | | | | | 5 | 8.2 |
| 21–24 | | 1 | 3 | 3 | 4 | 7 | 4 | | 1 | | 1 | | | | | | | | 25 | 8 |
| 25–28 | | 1 | 1 | 6 | 11 | 8 | 1 | 3 | | | | | | | | | | | 31 | 7.3 |
| 29–32 | 1 | 1 | 5 | 3 | 2 | 6 | | 3 | | | 2 | | | | | | | | 23 | 7.3 |
| 33–36 | 1 | 1 | 3 | 1 | 4 | 3 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | | | | 20 | 8.3 |
| 37–40 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | 3 | |
| 41–43 | | | | | | 3 | | | | | | | | | | | | | 3 | |
| Totals | 3 | 5 | 12 | 14 | 22 | 28 | 7 | 9 | 2 | 1 | 4 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 111 | 7.7 |

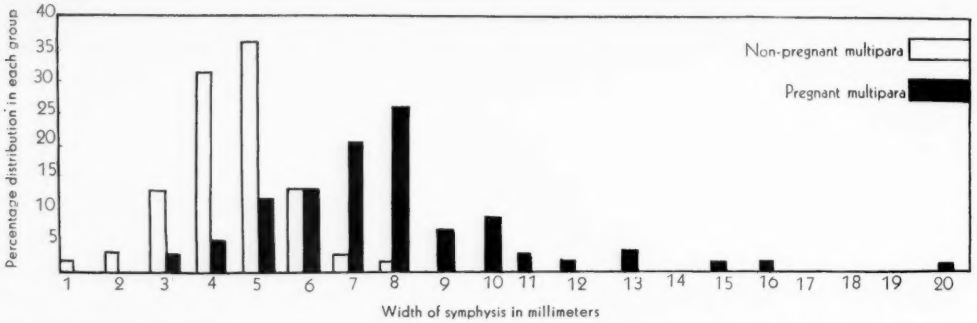



Fig. 5. Composite table showing comparative measurements of width of pubic gap in groups of non-pregnant women who have borne children (90 individuals) and similar group of pregnant women (111 individuals). X-ray pictures made in last two months of pregnancy.

different age groups into which the patients were divided showed only slight difference so that age appeared to have very little relation to the changes. The most striking finding was the great degree of variation between the symphyseal width of different individuals which tended to make the average figure unrepresentative of the group. The maximum was 20 millimeters and the minimum 3 millimeters. The width of the symphysis was 9 millimeters or more in 27, or 24.3 per cent. The measurements are shown graphically in comparison with those of a similar control group of non-pregnant women (Fig. 5). This makes more apparent the striking shift of the measurements of the symphysis to larger size in pregnancy.

TABLE IV.—MEASUREMENTS OF SYMPHYSIS OF 25 CONSECUTIVE PRIMIPARÆ

| Cases | Width of symphysis mm. | Age | Time of examination before delivery |
|---|---|---|---|
| 1 | 4 | 29 | 42 days |
| 3 | 5 | 25, 28, 31 | 1 day, 59 days, 29 days |
| 1 | 6 | 26 | Probably about 1 month |
| 6 | 7 | 18, 18, 19<br>19, 20, 21 | 34 days, 57 days, 48 days<br>3 days, 44 days, 30 days |
| 7 | 8 | 18, 20, 21<br>22, 23, 26<br>32 | 44 days, 28 days, 43 days<br>15 days, 3 days, 25 days<br>7 days |
| 4 | 9 | 19, 27<br>29, 30 | 14 days, 44 days<br>27 days, 26 days |
| 1 | 12 | 26 | 14 days |
| 1 | 13 | 23 | 1 day |
| 1 | 14 | 20 | 16 days |

2. *Second group.* In order to get a better idea of the incidence and degree of pubic separation and to see what part previous pregnancies played in weakening the articulations and whether this accounted for the large number of patients with abnormally wide separation in the multiparous group, roentgenological measurements were made of a group of 25 primiparæ in their last 2 months of pregnancy. These patients were chosen consecutively as they presented themselves at the clinic so that there was no selection and the measurements present as nearly as the small size of the group permits a true cross section of all primiparæ. The measurements are shown in Table IV. They are also represented graphically in comparison with those of a similar control group of non-pregnant nulliparæ (Fig. 6).

The average of the 25 measurements was 7.9 millimeters which agrees closely with the average of 7.7 millimeters obtained in the multiparæ (Group 1.) In this group 7, or 28 per cent measured 9 millimeters or over which compares with 24.3 per cent for the multiparous group. Here again the study seemed to show that the symphyseal widening occurred independently of any relation to age.

The measurements of the primiparæ are compared on a percentage basis with those of the multiparæ in Table V and the comparison is also shown graphically (Fig. 7). We may conclude from the study of these two groups that there is no essential difference

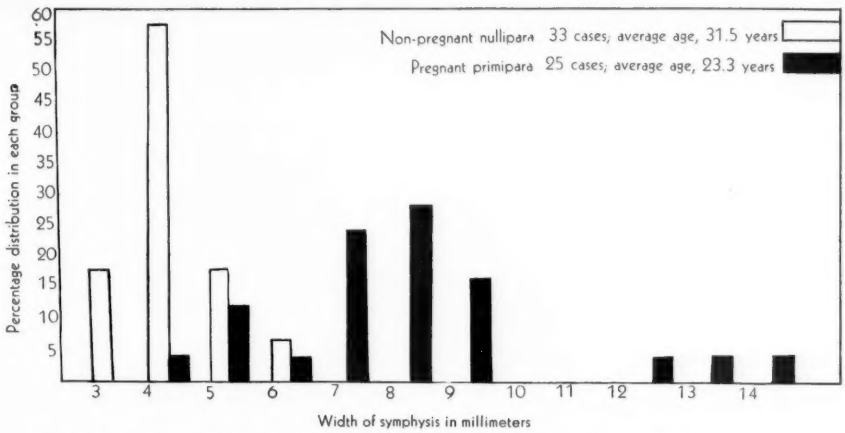

Non-pregnant nullipara 33 cases; average age, 31.5 years
Pregnant primipara 25 cases; average age, 23.3 years
Percentage distribution in each group
Width of symphysis in millimeters

Fig. 6. Composite table showing comparative symphyseal measurements in groups of non-pregnant nulliparæ and of pregnant primiparæ in last month of pregnancy.

between the behavior of the pubic articulation in primiparæ and multiparæ, that the symphysis regularly undergoes relaxation with an average increase of width of 3 to 4 millimeters, but that in about 25 per cent of individuals for some unknown reason the relaxation becomes much greater than this, sufficient in fact to be considered a pathological separation.

3. *Third group.* Finally an attempt was made to obtain consecutive roentgenological measurements at different periods both antepartum and postpartum in a group of pregnant women. This group comprised 38 individuals with 93 observations, chiefly patients who complained of symptoms that were thought to be due to pelvic instability or others in whom pubic separation was suspected because of the clinical findings at the time of examination. In spite of special efforts that were made to follow these patients, some were lost and no additional measurements obtained. Also some were only seen for the first time following delivery when symptoms referable to the pelvis were first noted. In these cases antepartum X-ray films showing the symphysis were generally lacking and earlier measurements of the width of the symphysis could not be obtained. Although the data are incomplete, they yield considerable information in respect to the

TABLE V.—PUBIC MEASUREMENTS OF PRIMIPARÆ AND MULTIPARÆ MADE BY X-RAY EXAMINATION IN LAST TWO MONTHS OF PREGNANCY.

| Width of pubis—mm. | Primiparæ | | Multiparæ | |
|---|---|---|---|---|
| | No. | Per cent | No. | Per cent |
| 3 | 0 | 0 | 3 | 2.7 |
| 4 | 1 | 4 | 5 | 4.5 |
| 5 | 3 | 12 | 12 | 10.8 |
| 6 | 1 | 4 | 14 | 12.6 |
| 7 | 6 | 24 | 22 | 20 |
| 8 | 7 | 28 | 28 | 25.2 |
| 9 | 4 | 16 | 7 | 6.3 |
| 10 | 0 | 0 | 9 | 8.1 |
| 11 | 0 | 0 | 2 | 1.8 |
| 12 | 1 | 4 | 1 | .9 |
| 13 | 1 | 4 | 4 | 3.6 |
| 14 | 1 | 4 | 1 | .9 |
| 15 | 0 | 0 | 1 | .9 |
| 16 | 0 | 0 | 1 | .9 |
| 17 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 |
| 20 | 0 | 0 | 1 | 9 |
| Totals | 25 | 100 | 111 | 100 |
| Aver.—mm. | 7.9 | | 7.7 | |

TABLE VI.—MEASUREMENTS OF 38 PREGNANT WOMEN AT DIFFERENT PERIODS, ANTE-AND POSTPARTUM

| Parity | Symptoms | Onset of symptoms | Months of pregnancy | | | | | | Delivery | First month | | Months postpartum | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | IV | V | VI | VII | VIII | IX | | 1–14 days | 15–28 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| I | Pubic | 2 weeks post partum | | | | | | | | | 5 | | | | | | | | | | | | 3 | |
| III | None | | | | | | | | | | | 5 | | | | | | | 3 | | | | | |
| III | Pubic and back | 9th mo. | 5 | | | | | | | | 5 | | | 4 | | | | | | | | | | |
| III | Sacro-iliac | 6th mo. | | | | | | | | 5 | | | | | | | | | | | | | | |
| I | Sacro-iliac | 8th mo. | | | | | | | | 6 | | | | | | | | | | | | | | |
| II | Sacro-iliac and pubic | 6th mo. | | | | 6 | | | 6 | | | | 5 | | | | | | | | 4 | | 4 | |
| II | Pubic | 5th mo. | | | | | | | 7 | | | | | | | | | | | | | | | |
| II | None | | | | | | | | 7 | | | | | | | | | | | | | | | |
| I | Sacro-iliac | 7th mo. | | | | 7 | | | | | | | 5 | | | | | | | | | | | |
| I | Sacro-iliac and pubic | 9th mo. | | | | | | | 7 | | | | | | | | | | | | | | | |
| IV | Pubic | 2nd mo. | | | | 7 | | | 7 | 5 | | | 5 | | | | | | 3 | | | | | |
| III | Pubic | 8th mo. | | | | | 8 | | | 7 | | | | | | | | | | | | | | |
| I | None | | | | | 7 | | | | 9 | | | 6 | | | 5 | | | | | | | | |
| I | Sacro-iliac and pubic | 9th mo. | | | | | 9 | | | 9 | | 6 | | | | 6 | | | | | | | | |
| I | Sacro-iliac | 9th mo. | | | | | | | | 8 | | | | | | | | | | | | | | |
| I | Low back | 8th mo. | | 5 | | | | | | 8 | | | | | | | | | | | | | | |
| I | Pubic | 9th mo. | | | | | 7 | | | | | | | | | | | | | | | | | |
| III | Low back | 5th mo. | | | 8 | | | | | | | | | | 5 | | | | | | | | | |
| II | Sacro-iliac | 9th mo. | | | | 6 | | | | 8 | | | | | | | | | | | | | | |
| II | Sacro-iliac and pubic | 9th mo. | | | | | 9 | | | | 7½ | | | | | | | | | | | | | |
| I | Sacro-iliac and pubic | 9th mo. | | | | 9 | | | | | | | | | | | | | | | | | | |
| III | Sacro-iliac and pubic | 8th mo. | | | | | 9 | | | 10 | | | | | 7 | | | | | | | | | |
| III | Sacro-iliac | 8th mo. | | | | | | 10 | | | | | | 3 | | | | | | | | | | |
| IV | Sacro-iliac | 8th mo. | | | 10 | | | | | 11 | | 6 | | | 5 | | | | | | | | | |
| III | Sacro-iliac and pubic | 6th mo. | | | | 10 | | | | 11 | | 5 | | | | | | 5 | | | | | | |
| III | Sacro-iliac | 8th mo. | | | | 11 | | | | | | | | | | | | | | | | | | |
| IV | Sacro-iliac and pubic | 8th mo. | | | 11 | | | | | | | | | | | | | | | | | | | |
| III | Sacro-iliac and pubic | 8th mo. | | 11 | | | | | | | | | | | | | | | | | | | | |
| V | Sacro-iliac and pubic | 5th mo. | | | | | | | | 12 | | | | | | | | | | | 6 | | | |
| IV | Sacro-iliac | 7th mo. | | | | | | 12 | | | | | | | | 6 | | | | | | | | |
| I | Sacro-iliac | 8th mo. | | | | 11 | | | | 12½ | | | | | | 6 | | | | | | | | |
| I | Sacro-iliac and pubic | 4th mo. | | | | | 12 | | | 9 | 7 | | | | | | | 5 | | | | | | |
| V | * | | | | | | | | | 13 | 16 | | | | | | | | | | | | | |
| I | Pubic | Post partum | | | | | | | | | | 15 | | 9 | | | | | | | | | | |
| II | Pubic | 5th mo. | | 12 | | | | | | 17 | 9 | 66 | | | 4½ | | | | | | | | | |

*Developed osteomyelitis of symphysis after delivery.

TABLE VI.—MEASUREMENTS OF 38 PREGNANT WOMEN AT DIFFERENT PERIODS, ANTE-AND POSTPARTUM—Continued

| Parity | Symptoms | Onset of symptoms | Months of pregnancy | | | | | | Delivery | First month | | Months postpartum | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | IV | V | VI | VII | VIII | IX | | 1–14 days | 15–28 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| III | Sacro-iliac and pubic | 4th mo. | 6 | | | | 18 | | | 14 | 3 | | | | | | | | | | | | | |
| II | Sacro-iliac and pubic | 8th mo. | | 13 | | | | | | 18 | | | 8 | | | | | | | | | | | |
| IX twins | None | | | | | | 34 | | | 35 | 16 | 10 | | 8½ | | | | 8 | | | | | | |

development and retrogression of the process of pubic relaxation (Table VI and Fig. 8).

As to the period of pregnancy in which relaxation of the symphysis begins, this is evidently early. The earliest measurements were made in the fourth month and then only in two individuals, but in both the width was greater than that to which the symphysis retrogressed later so that we considered some degree of relaxation was already present. Wide measurements indicative of relaxation were obtained in one of two individuals examined in the fifth month, and in all of the 5 women who were examined in the sixth month. The observations are meager, but they indicate that the process begins in the first half of pregnancy.

The measurements further show very little tendency to increase of the relaxation in the last 2 or 3 months of pregnancy. The process of parturition seems to have very little effect in increasing the width of the symphysis. Of 15 patients in whom comparative measurements were obtained both antepartum and within a few days after delivery, the width of the symphysis increased in 9, remained stationary in 1, and diminished in 5. The increase amounted to 1 to 2 millimeters in 7, and to 5 millimeters in 2 individuals, but in both of the latter patients the previous measurements had been made in the sixth month, and we have no knowledge of the amount of widening of the symphysis that had occurred in the meantime.

Retrogression of the symphyseal relaxation began in the first month postpartum and apparently was fairly well complete by the end of 3 to 5 months. An artificial factor enters in here as most of the patients with wide separation were treated by various orthopedic appliances, and it is impossible to determine in what degree the results were modified by the treatment.

Comparing the measurements of those individuals in whom both antepartum and late postpartum examinations were obtained, we have evidence of retrogression amounting to 1 millimeter in 1 patient; 2 millimeters, in 3; 3 millimeters, in 2; 4 millimeters, in 1; 5 millimeters, in 3; 6 millimeters, in 1; 7 millimeters, in 2; 8 millimeters, in 1; 15 millimeters, in 1; and 26 millimeters, in 1. The average was 7.7 millimeters, decrease from the maximum width. The general course of relaxation and retrogression of the symphysis is shown in Figure 8 in which the consecutive measurements of 20 patients are plotted in individual curves.

4. *Roentgen appearance of symphysis.* Slight but definite changes in the appearance of the symphysis during pregnancy apart from the separation were shown by roentgenological examination. These seemed to consist in thinning and absorption of the cortical layer at the pubic margins, the development of slight proliferative changes tending to give an appearance of greater irregularity to the symphyseal space and the occasional appearance of small, round cyst-like areas of diminished density in the body of the pubic bone.

5. *Pubic mobility.* Movement of one pubic bone upon the other could almost invariably be demonstrated by tactile examination with the patient lying on her back, the examining finger on the symphysis, and an assistant simultaneously pushing on one leg and pulling on the other and then reversing the procedure. Pubic mobility could also be demonstrated by X-ray examination with the aid of this "push and pull" test. Two films were exposed, one

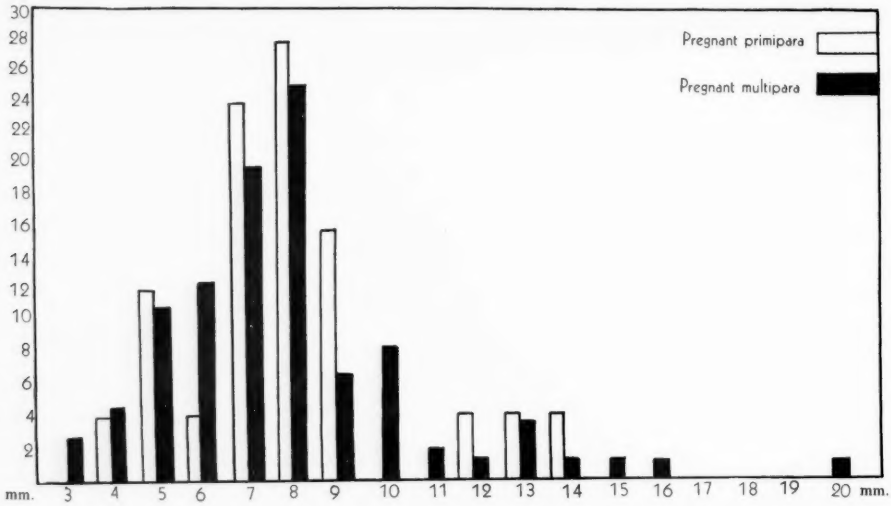



Fig. 7. Comparison between pubic width of pregnant primiparæ (25) and pregnant multiparæ (111). Measurements made in last 2 months of pregnancy.

with a push on the right leg and a pull on the other, and the second with the push and pull reversed. The amount of the excursion varied with the degree of pubic separation being greatest in the patients with the wide gaps. It was difficult to measure the amount of the motion accurately, and this was not done (Fig. 9).

We have since become familiar with the technique described by Chamberlain for measuring pubic mobility in which roentgenograms are made with the patient, standing upon a wooden block, bearing weight first upon the right and then upon the left leg with the other leg hanging free. This is a better method than the one we employed, and we shall make use of it in the future. Control tests using this method were made in 4 males between 25 and 32 years of age and in 5 non-pregnant nulliparæ between the ages of 21 and 33 years. In 2 of the males we were able to demonstrate mobility with an excursion of 0.5 to 2 millimeters, respectively, and also in 3 of the females, the excursion being 1, 1, and 2 millimeters, respectively.

Chamberlain uses the method for testing relaxation of the sacro-iliac joints and states that there is usually no measurable displacement in the male, but motion up to 0.5 millimeter is considered within normal limits; in the female the motion may be as much as 1.5 millimeters though 1 millimeter is more usual. He also says that very early in pregnancy the pelvic joints become relaxed thus permitting greater mobility. He considers increased pubic mobility one of the earliest signs of pregnancy.

## CAUSATION

The constancy of the phenomena of widening of the symphysis pubis in pregnancy as shown by these studies, the demonstration that the process begins in the first half of pregnancy and is already established by the end of the fifth to seventh month before pressure forces can have developed to any sufficient extent to play any part in determining the condition and the gradual retrogression of the process within a few months following the termination of pregnancy, all point to the biological nature of the process and permit the inference that the regulatory mechanism may be hormonal in nature.

The investigations of F. L. Hisaw, of the University of Wisconsin, have demonstrated beyond doubt the hormonal control of this process in certain mammals. He was able to demonstrate the presence of a hormone in the blood of guinea pigs, dogs, cats, sows, mares,

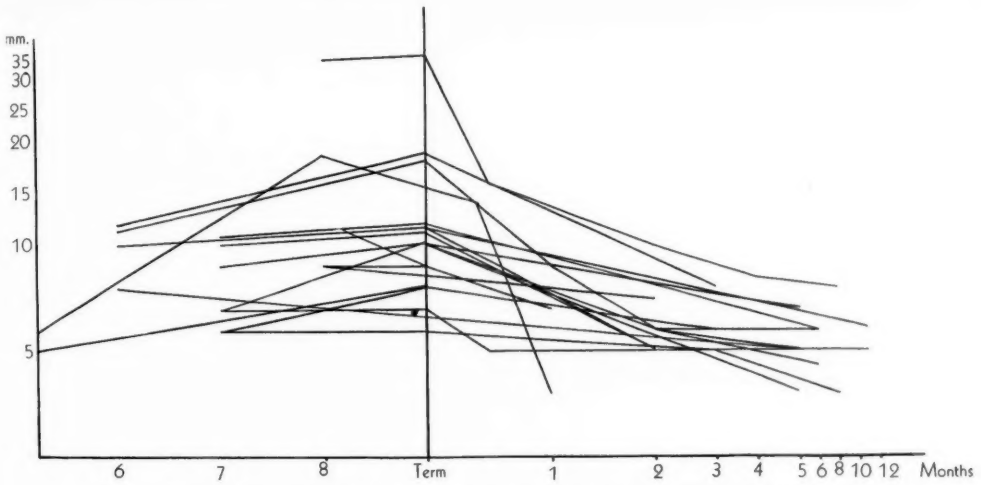



Fig. 8. Consecutive measurement both antepartum and postpartum in 20 pregnant individuals.

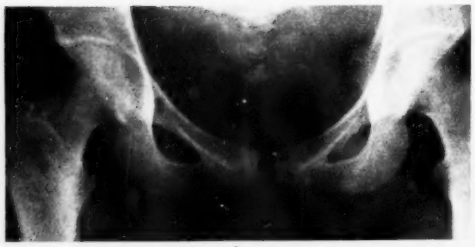
and rabbits during pregnancy which when injected into virgin guinea pigs during estrus would produce within 8 to 12 hours the same remarkable relaxation of the pelvic ligaments noted in those animals before parturition. In the rabbit this substance could be demonstrated 7 to 8 days after the beginning of pregnancy. It reached its maximum concentration by the twentieth day and was completely absent 12 to 18 hours after parturition. Later this substance was obtained in abundance from the placenta and corpus luteum of the sow. Subsequently he isolated the substance in relatively pure form and named it "relaxin." He was able to show that it is a special fraction of the corpus luteum hormone.

Hisaw found that the maximum response to relaxin occurred only during or close to estrus. Castrated females did not respond unless first brought under the influence of the follicular hormone theelin. He therefore concluded that neither theelin nor relaxin could alone elicit relaxation of the pelvis, but that the reaction was due to a "one-two" synergistic relationship between the two hormones. This "one-two" relationship has also been demonstrated in male guinea pigs in which the pubic bones are united by cartilaginous substance rather than by ligaments as in the mature females. By bringing castrated male animals under the influence of theelin he was able to convert the male symphysis into the feminine type, and relaxin was then able to induce ligamentous relaxation as in females.

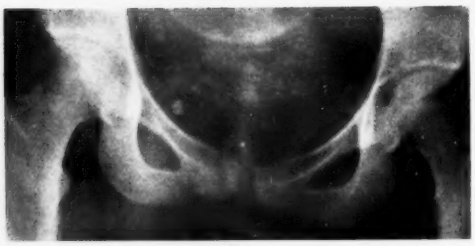
Study of the changes at the symphysis showed that two processes were involved in the ligamentous relaxation. Theelin produced a multiplication of the connective tissue elements of the symphysis pubis while relaxin caused a shift of the ligaments and rapid relaxation.

Attempts to demonstrate the presence of relaxin in the blood of pregnant women have thus far proved unsuccessful, and the same is also true in the case of cows. Hisaw came to the conclusion that while many mammals have special pelvic modifications to facilitate parturition, it is known that several of them must be accounted for on other grounds than those presented by the guinea pig. The facts indicate that the situation has been met in different biological ways which may or may not include hormonal activity.

To our minds, however, the facts concerning the process of symphyseal relaxation in pregnant women indicate a very close parallel to those found by Hisaw in certain mammals and strongly suggest some type of hormonal control.



A.



B.

C.

Fig. 9. X-ray pictures demonstrating mobility of the symphysis pubis in a woman near term. A. Patient flat on the table without traction on either hip. B. X-ray picture with traction on the right hip and counter pressure upward on the left hip. Note that the left side of the symphysis is higher than the right. C. Roentgenogram with traction on the left and counter pressure on the right. Note that the right side of the symphysis is now the higher.

ABNORMAL WIDENING OF THE SYMPHYSIS

Our measurements of the symphysis in pregnant women showed a number of instances in which the process of relaxation had gone to extreme limits. We previously referred to these as pathological. We believe that they deserve this appellation because they represent actual separation of the pubic bones instead of mere relaxation of the joints, and because they are usually associated with symptoms of pelvic instability. Yet they are different in degree only, and can be divided only by setting up an arbitrary standard of measurement. If 8 millimeters is taken as the upper limit of normal physiological relaxation, then we find that approximately 25 per cent of pregnant women show abnormal widening. In the cases studied by us, all degrees of separation were found with an extreme of 35 millimeters, or four times the normal.

These instances of wide pubic separation are the ones that have usually been reported in the literature as examples of traumatic rupture due to falls or other injuries in the antepartum period or resulting from operative delivery, or difficult labors of one kind or another. Traumatic rupture undoubtedly occurs, but we believe that it is rare and only one instance of it was encountered during our study. In this case, following the low application of forceps while strong traction was being exerted a loud snap was heard, and separation of the symphysis could then be demonstrated. We believe that the diagnosis of traumatic rupture is only justified when a direct sequential relationship between trauma and pubic separation can be shown as in this case.

As to the cause of abnormally wide separation we believe that there is no reason to suppose that it results from anything more than the normal physiological process which becomes exaggerated in certain individuals. It is a possible theory that it is due to an excess in the amount of the regulating hormone. That the stress and strain thrown upon the pelvic joints by the patient's activities, occupation, and weight may play part in causing further stretching of the ligaments is possible, but it is improbable that this would produce any effect unless the ground had already been prepared by the physiological processes. Also to be considered is the possible effect upon the weakened pubic ligaments of pressure forces exerted by the contents of the uterus. In favor of this is the observation that the widest separation encountered in our series was in a woman with a twin pregnancy, but on the other hand the fact that the measurement was already 34 millimeters in the seventh month, and that it did not increase thereafter during the period in which the uterine contents greatly enlarged would argue against this playing any

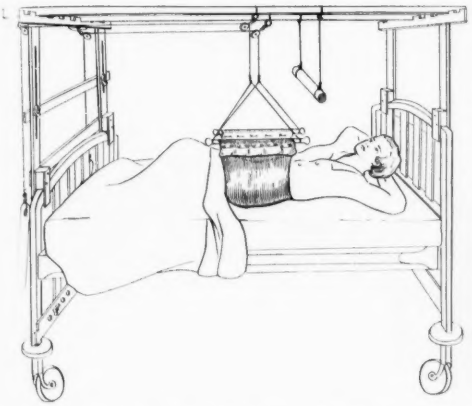


Fig. 10. Drawing of patient in muslin sling suspended by an overhead frame by two weights of approximately 20 pounds each.

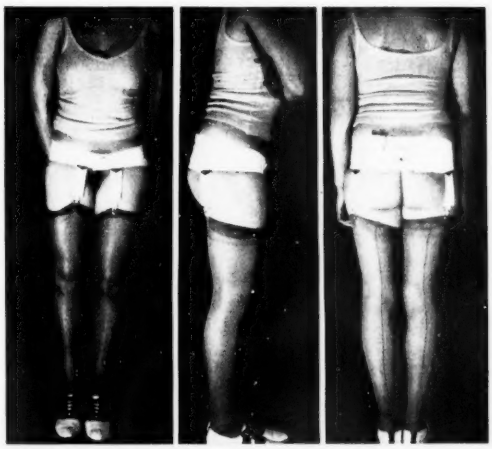


Fig. 11. Pelvic belt worn by ambulatory patients after sling treatment in bed. It can be used for bed treatment in mild cases.

great part. Also contradicting this theory was the case of a woman delivered of an anencephalic monster with an associated hydramnios of marked degree, who showed a maximum separation of only 8 millimeters.

### SIGNS AND SYMPTOMS OF PELVIC INSTABILITY

Many pregnant women complain of symptoms that are directly referable to the stretching of the pelvic joint ligaments and the ensuing pelvic instability. The true significance of these symptoms is not generally appreciated, and they are classed as part of the general and necessary discomforts of pregnancy. Numerous examples were encountered as soon as we began to question patients. Within a period of 3 months one of us was able to collect 33 cases.

The symptoms may be referable to the pubic joint alone, to the sacro-iliac joints alone, or to a combination of both. The pubic symptoms are the more common and consist of pain in the region of the symphysis, occasionally referred down the inner side of the thighs, usually worse when beginning to move after sitting or lying. There may be a sensation of snapping or movement of the bones when walking, and there is frequently complaint of inability to walk normally. The sacro-iliac symptoms are chiefly backache and pain localized over one or both sacro-iliac joints. Pain of the sciatic type, referred down the leg occurs, but was encountered in only one patient of our series and then postpartum and following a complicating pneumonia. In a certain number of patients, both groups of symptoms are present in combination.

On examination a waddling gait is frequently noted and in the patients showing this a positive Trendelenburg's sign can usually be demonstrated, that is, when the patient stands on one leg there is inability to hold the pelvis in the horizontal plane and the opposite buttock drops. This may be present on one or both sides. Palpation of the symphysis shows marked localized tenderness, this being one of the most constant findings. Depending upon the degree of separation the presence of a sulcus at the symphysis may be noted. In some cases one or even two fingers may be laid between the pubic bones. This is even more marked on bimanual examination. Pubic mobility may be demonstrated by the "push and pull test" upon the legs performed by an assistant. In the patients with sacro-iliac symptoms tenderness on pressure can be demonstrated over the posterior sacro-iliac ligaments and in the region of the sacro-sciatic notch. Motions of the hips are usually free but occasionally limited because of pain in the region of the sacro-iliac or pubic joints on extension from the flexed position. We rarely

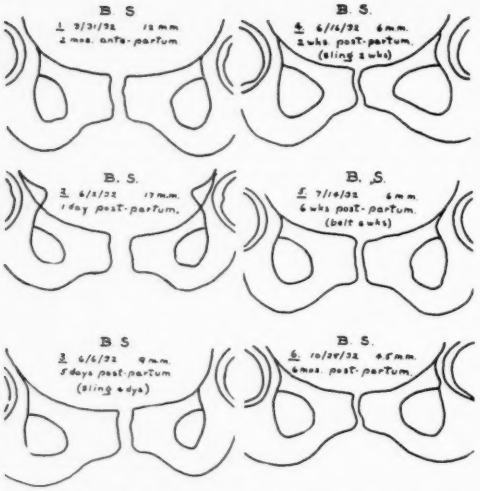



Fig. 12. X-ray tracings of a woman in her second pregnancy. Delivery June 1, 1932. There was marked mobility of the symphysis and X-ray examination suggested widening of the sacro-iliac joints. Placed in sling for 2 weeks after which symphysis returned to normal.

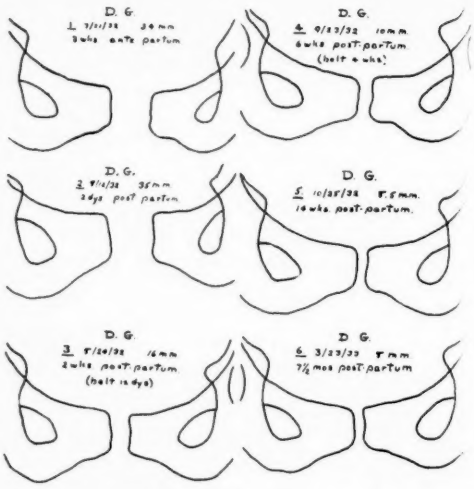



Fig. 13. X-ray tracings of a woman in her ninth pregnancy (twins). Delivery took place on August 10, 193 There was marked mobility of the symphysis. Th patient wore a belt for a period of 4 months followin delivery.

found any restriction or pain on flexing the hips with the knees extended.

While the severity of the symptoms corresponded in a general way to the amount of separation of the symphysis that could be demonstrated by X-ray, this relationship was by no means constant. Several women in whom no more than the average amount of relaxation was present complained of symptoms and some of the patients in whom marked separation occurred made no complaint whatever. A striking instance of this was the woman with the maximum separation of 35 millimeters and twins. She was in her ninth pregnancy and walked with a marked waddle, but had no complaints. She was a large, rather stolid woman who had become more or less philosophical about child bearing, and most women in her situation would probably have had many and bitter complaints. It was also noticed that in the case of the women who complained of symptoms but in whom only slight or average relaxation of the symphysis could be demonstrated, the symptoms were more apt to be sacro-iliac in nature than pubic. In the women with marked separation the symptoms were more often pubic.

Of 30 cases examined because of pelvi symptoms, palpable mobility at the pubis wa demonstrated in 28, pubic tenderness wa present in 25, and a waddling gait was noted i 13. The separation of the symphysis in th latter cases was distinctly greater than th average, 7 measuring over 10 millimeters, an only 2 showing little or no separation.

The onset of symptoms was noted in th second month of pregnancy in 1 instance, i the fourth month in 2, the fifth month in 4, and in the sixth month in 3. The great ma jority (20) first began to complain in the last 2 months of pregnancy. Several of the wome complained of pelvic symptoms only follow ing delivery, and pubic separation was the demonstrated by X-ray examination.

Twenty-four women with pubic separatio who had had previous children were ques tioned in regard to the occurrence of pelvi symptoms in former pregnancies. About hal (11) had had no symptoms. Of the remainde 7 had had pain in the pubic region, 6 sacro iliac symptoms, and 2 had had discomfort i both regions. One woman gave a definit history of former pubic separation, and ha received orthopedic treatment. Her sym

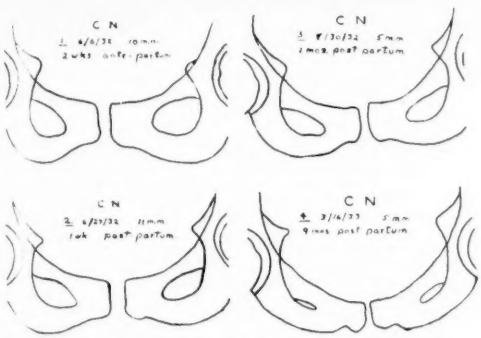



Fig. 14. X-ray tracings of a woman in her second pregnancy. Delivery June 22, 1932. X-ray films showed both absorptive and productive changes.

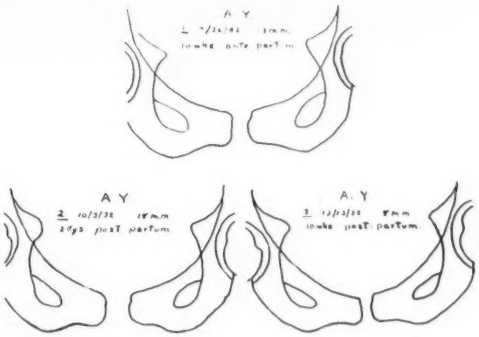



Fig. 15. X-ray tracings of woman in second pregnancy. Delivery October 1, 1932. Marked mobility of symphysis; cystic changes (not shown in tracings).

physis came apart in the seventh month of her subsequent pregnancy and she suffered from great discomfort due to this cause.

### TREATMENT OF PELVIC JOINT RELAXATION

In view of the fact that pelvic joint relaxation is a normal physiological accompaniment of pregnancy the question will be asked whether any treatment is indicated, and to this we would reply in the affirmative. Treatment is indicated in the antepartum period to relieve symptoms and to increase the patient's comfort. Further it may limit the amount of symphyseal widening and prevent it from reaching the stage of pathological separation. In the postpartum period early intensive treatment will quickly bring about closure of the symphysis and prevent the development of a condition of chronic relaxation of the pelvic joints, the frequent prelude to chronic backache, recurrent sacro-iliac strains, and other conditions that account for a great deal of later discomfort among women who have borne children.

In the antepartum period, treatment is indicated only when the patient complains of symptoms referable to the pelvic joints or when evidence of abnormal widening of the symphysis is found on examination. Since the latter condition may develop in the absence of symptoms, the obstetrician should systematically include the symphysis pubis in his general routine of examination of the pregnant patient. When in doubt as to the exact condition he should have recourse to the help of the roentgen ray. For treatment at this period, we have employed a simple type of webbing belt (Fig. 11) which makes pressure only about the pelvis and the patients have generally obtained prompt relief from its use. Adhesive strapping may be used as a less efficient and less comfortable substitute.

It is in the immediate postpartum period, however, that treatment is most urgently indicated. Retrogression of the pelvic joint relaxation begins immediately following delivery and proceeds slowly over a period of several months before reaching a static condition. When an abnormal degree of separation of the symphysis pubis exists and the patient is allowed to become ambulatory, there is danger that the excessive mobility of the bones together with the stress and strain thrown upon the joint by the patient's activities may interfere with the normal involution and that a condition of chronic relaxation may persist. This condition was observed in 3 patients of our series who did not receive any treatment; in 1 the symphysis retrogressed to a width of 12 millimeters at the end of 10 months, and she still complained of pain at the pubis; in another to 8 millimeters at the end of 3 months; and in a third only to 9 millimeters at the end of 4 months during which time she had been almost entirely disabled.

On the other hand, with prompt recognition of the condition at the time of delivery and immediate institution of treatment while the patient is recumbent, the pubic bones can be

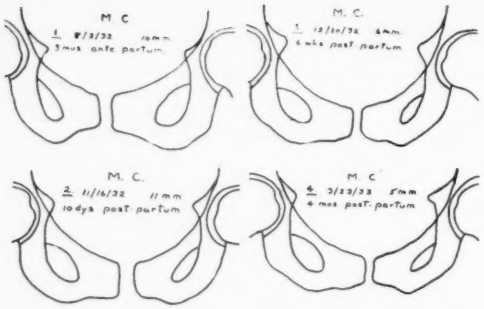



Fig. 16. X-ray tracings of a woman in her fourth pregnancy. Delivery took place on November 15, 1932. The patient showed marked mobility and some cystic irregularity of the symphysis (this is not shown in the tracings).

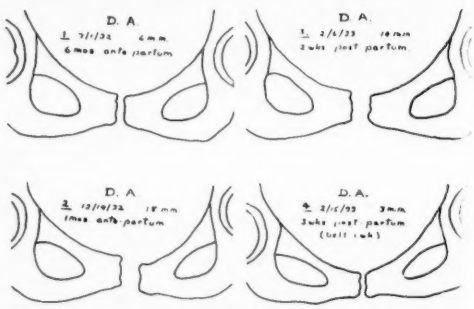



Fig. 17. X-ray tracings of a woman in her third pregnancy. Delivery on January 24, 1933. Two weeks after delivery she was placed in a sling, following which she wore a belt. Closure of the symphysis did not occur until treatment was begun and then progressed rapidly.

approximated promptly and the ligaments permitted to tighten to the utmost while still malleable. The most efficient appliance for overcoming the separation and also the most comfortable is the muslin sling suspended from an overhead frame by two weights of approximately 20 pounds each (Fig. 10). This apparatus promptly brought about closure of the symphysis when employed by us and at the end of the usual postpartum recumbent period of 2 weeks, the ligamentous slack had been taken up sufficiently to permit the patients to become ambulatory with the support of a pelvic belt (Fig. 11) without any recurrence of the separation.

Here again everything hinges upon an early recognition of the separation. The obstetrician has an unequalled opportunity at the time of delivery to examine the symphysis pubis and to ascertain the degree of separation that is present. When in doubt he can always fall back upon X-ray examination to settle the question. (Figures 12 to 17 show series of typical cases with abnormal separation of the symphysis pubis. The X-ray tracings show the changes that occur before and after delivery with the amount of separation measured in millimeters. When treatment was given it is indicated.)

## CONCLUSIONS

1. Relaxation of the pelvic joints and particularly of the symphysis pubis is a normal accompaniment of pregnancy.

2. Relaxation of the symphysis begins in the first half of pregnancy, progresses but slightly in the last 3 months, and is but little affected by parturition. Retrogression begins immediately following delivery, and is usually complete by the end of 3 to 5 months.

3. The process of relaxation is physiologic and is probably the result of a hormonal activity.

4. Abnormal separation of the symphysis pubis occurs in about 25 per cent of the cases and probably results simply from an exaggeration of the normal physiological process; only exceptionally does trauma play any part.

5. Symphyseal relaxation is accompanied by an increase of pubic mobility and is frequently associated with characteristic symptoms resulting from instability of the pelvic joints.

6. Treatment is indicated to relieve symptoms and to prevent the development of a condition of chronic relaxation of the pelvic joints which is frequently responsible for a great deal of later discomfort among women who have borne children.

7. The key to the situation lies in prompt recognition of abnormal separation of the symphysis when present, and in order to detect this the obstetrician should include the symphysis pubis in his regular routine of examination of the pregnant patient both antepartum and at the time of delivery.

## BIBLIOGRAPHY

### ARTICLES REFERRED TO IN THE TEXT


1. BARLOW. Monthly J. M. Sc., Edinburgh, 1854, p. 83.
2. BOLAND, BENEDICT F. Separation of symphysis pubis. New England J. Med., 1933, cviii, 431.
3. BREHM, W., and WEIRAUCH, H. V. Am. J. Obst. & Gynec., 1928, xv.
4. CANTIN, LOUIS. Relochement des symphyses et arétralgies pelviennes d'origine gravidique. Thèse de doct., Par., 1899.
5. CHAMBERLAIN, W. E. Symphysis pubis in the roentgen examination of the sacro-iliac joint. Am. J. Roentgenol., 1930, xxiv, No. 6.
6. CUNNINGHAM, D. J. Text-book of Anatomy. 5th ed. New York: William Wood & Co., 1923.
7. FEVOLD, H. L., HISAW, F. L., and MEYER, R. K. Proc. Soc. Exper. Biol. & Med., 1930, xxvii, 27.
8. GOLDTHWAIT, J. E., and OSGOOD, R. B. Boston M. & S. J., 1905, clii, 593.
9. HEYMAN, JAMES, and LUNDQUIST, ARVID. The symphysis pubis in pregnancy and parturition. Acta obst. et gynec. Scand., 1932, xii.
10. Idem. J. Exper. Zool., 1925, xlii, No. 4.
11. Idem. Physiol. Zool., 1929, ii, No. 1.
12. Ibid. 1930, iii, No. 1.
13. HISAW, F. L. Sex and Internal Secretions, 1932.
14. HISAW et al. J. Am. Chem. Soc., 1932, liv.
15. JOHNSON, CLAYTON R. Stereoroentgenometry. A method for mensuration by means of the Roentgen ray. Am. J. Surg., 1930, viii, 151.
16. KNOX. Lancet, 1839, 1840; Med. Gaz., 1843.
17. LE GALLOIS. Experiences sur la vie (Appendix). Translated by N. C. and J. G. Nancrede. Philadelphia, 1913.
18. LUSCHKA. Arch. f. Gynæk., 1912, xcvi.
19. LYNCH, FRANK W. The pelvic articulations during pregnancy, labor, and the puerperium. Surg., Gynec. & Obst., 1920, xxx, 575.
20. PUTSCHAR, W. Zur Pathologie der Symphyse. Verhandl. d. deutsch. path. Gesellsch., 1930, xxv, 214.
21. REIS, BAER, ARENS, and STEWART. Traumatic separation of symphysis pubis during spontaneous labor with clinical and X-ray study of normal symphysis pubis during pregnancy and puerperium. Surg., Gynec. & Obst., 1932, lv, 336.
22. SNELLING, F. G. Relaxation of the pelvic symphyses during pregnancy and parturition. Am. J. Obst., 1870, ii, 561.
23. WU, LIEH-CHUNG. Nat. M. J. China, 1930, xvi.


### ADDITIONAL REFERENCES


1. BAUDELOCQUE. Midwifery. Abridgement of Heath's Translation. 3d ed. Edited by Wm. P. Dewees. 1823.
2. DUNCAN. Researches in Obstetrics. Edinburgh, 1868.
3. EICHELBERG. Rusts Magazine, xvii, pt. 3, 550.
4. EYMER. Die Roentgenstrahlen in Gynaekologie und Geburtshilfe, 1913.
5. GRAVES, W. P. Gynecology. 4th ed., 1928.
6. Idem. Female Sex Hormonology, 1930.
7. HUNTER, W. On the symphysis pubis. Medical Observer and Inquirer, London, 1762, ii, No. 28.
8. JACQUEMIER. Manuel des accouchements, ii, 476.
9. LACHAPELLE. Pratique des accouchements, iv, 85.
10. LANG, F. J., and HASLHEFER, L. Arch. Surg., 1932, xxv, November.
11. LUSCHKA. Arch. f. path. Anat., 1854, vii.
12. MCNAMARA. Surg., Gynec. & Obst., 1916, xxiii, 625.
13. MUELLER, W. Zentralbl. f. Gynaek., 1931, lv.
14. NICHOLSON. Tr. Roy. Soc. Phys., Ireland, 1824, iv.
15. POULLET. De la rupture des articulations du bassin pendant l'accouchement. Lyon méd., 1864.
16. SENOIR. Bull. Acad. nation. de méd., 1851, xvi, 15.
17. SMELLIE. Midwifery. New Sydenham Society, 1877, ii, 5.
18. SPIGELIUS. Anat., lib. II, cap. xxiv.
19. TERNIER and CHANTREUIL. Traite de l'art des accouchements, 1888, i, 238.
20. WALTER. Von de Spaltung der Schambein. Berlin, 1782.
21. WOOD, JOHN. Pelvis. Cyclopedia of Anatomy and Physiology. 1859, v.
22. ZAGLAS. Month. J. M. Sc., Edin., 1851, September, p. 289; 1851, November, p. 489.

# CHRONIC FOLLICULAR GASTRITIS

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THE operation of gastric resection, now largely replacing gastro-enterostomy in the surgical treatment of peptic ulcer, has placed valuable fresh material in the hands of the pathologist. As a consequence, the study of chronic gastritis has become increasingly popular, due chiefly to the continental writers who believe that the workers in the British Isles and this continent pay the subject too little attention. In a recent communication Lindau and Wulff sum up the views of the former by saying "undoubtedly the most important observation (i.e. with reference to peptic ulcer) made of late years is the regular appearance in ulcer cases of a gastritis-like change confined to the pyloric portion of the stomach. Konjetzny and his collaborators have pointed out the constant occurrence (up to 100 per cent) of these gastritic changes and have demonstrated a relationship between them and the fully developed ulcer."

About a century ago gastritis was advanced by Broussais as the alleged cause of most pathological phenomena. These early records are confusing, however, as postmortem digestion and putrefaction were often interpreted as signs of inflammation. Now, radical surgical procedures furnish fresh material which can be placed in fixative solutions in the operating room. Heyrowsky, in 1913, studied fragments of the gastric wall removed at gastro-enterostomy in cases of ulcer or cancer, and in these he found an inflammatory change constantly present. In a review of 40 cases of gastric ulcer, Sole found an associated gastritis in every instance. Recently Fitzgerald placed on record 9 cases of chronic follicular gastritis with symptoms or signs suggesting chronic ulcer, but with the absence of such findings at operation or in the gross specimen. A long list of similar cases have been reported during the past 10 years and numerous authors (Konjetzny, Faber, Fitzgerald, etc.) now recognize chronic follicular gastritis as a clinical and pathological entity.

Chronic gastritis may be defined as an infiltration into the stomach wall, chiefly the mucosa, of chronic inflammatory cells. In about 50 per cent of the cases (6), there is a pronounced hyperplasia of the lymphoid tissue (follicular apparatus), and in this instance the lesion is referred to as "chronic follicular gastritis."

The present study embraces material removed from the stomach wall in an almost consecutive series of 56 cases of gastric resection in this hospital over a recent period of several months. The resections varied greatly in extent, in several instances the major portion of the organ being included. The tissue was placed in a fixative solution as soon as possible. Our first problem was to establish what might be considered a normal organ and for this purpose stomachs from an unpicked series of 24 autopsies were examined, discarding only those which showed considerable evidence of postmortem change. Numerous sections were taken for microscopic study from representative areas, and in studying the surgical specimens sections were taken from the same relative areas, as far as possible, in order to facilitate comparisons.

The normal mucous membrane has a greyish-pink color, and in the empty stomach forms numerous high, longitudinal folds, the rugæ. The surface epithelium covers the free surface of the mucosa and dips down into the necks of the gastric glands. It begins abruptly at the cardia and is replaced by intestinal epithelium at the pylorus. It has the same structure in all parts of the stomach—a tall simple columnar epithelium with cells filled with mucigen granules which furnish the layer of alkaline mucus for lubrication of the mucosa.

Beneath the surface epithelium is the lamina, or tunica propria, a loose connective tissue framework which supports the glands. This delicate network forms larger accumulations between the neck of the glands and contains a varying number of cells. Besides oval pale nuclei which seem to belong to fibroblasts, or reticular cells, the meshes contain

Fig. 1. Chronic follicular gastritis, duodenal ulcer. The glands are separated by the extensive chronic inflammatory infiltration. One large lymph follicle with hyperplastic germinal center.

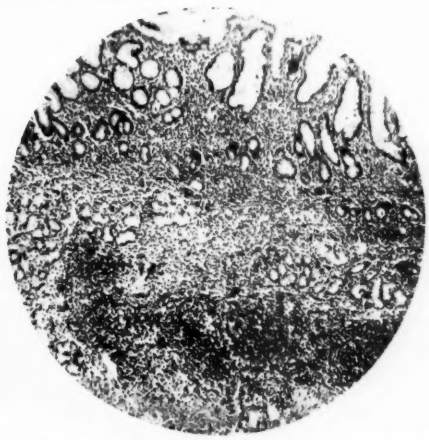

Fig. 2. Chronic gastritis, adenocarcinoma. Extensive lymphocytic infiltration in the depths of the mucosa with thickening and infiltration of the muscularis mucosæ.

frequent free elements, mostly lymphocytes, but also a few plasma cells and eosinophiles. In the deeper portions of this lamina small spherical accumulations of lymphoid tissue occur normally. These are more numerous at the pyloric and also the cardiac end. In the autopsy stomachs studied, we found these lymphoid follicles were relatively few in number and in about 30 per cent of cases were not found at all. In a very small number their germinal centers were hyperplastic.

The glands of the stomach are of three types. The cardiac glands form a narrow ring about the cardia, are similar to those found in the œsophagus, and at present, while their function is unknown, they are probably merely mucus producing glands. The pyloric glands occupy the pyloric region and are lined by cuboidal cells similar to those found in the cardiac glands or the necks of the fundic glands. These cells are mucus secreting. The gastric glands proper, or fundic glands, occupy the fundus and proximal two-thirds of the stomach. These are the most important glands; they are closely arranged and penetrate the whole thickness of the mucosa. They are composed of, first, the chief or zymogenic cells which are pyramidal cells with a spherical nucleus. These are found in the lower half of the gland and contain granules believed to be pepsinogen. The parietal cells are slightly triangular cells which lie between the chief cells and the basement membrane and are more numerous toward the neck of the gland. These stain deeply with eosin and are believed to secrete hydrochloric acid or its precursor. The necks of the glands are lined by mucus secreting cells similar to the surface epithelium. These cells then are responsible for the secretion of the gastric juice and are aided by the pyloric glands which also secrete some pepsin, alkaline in reaction.

The line of demarcation between the fundic and pyloric gland areas is less well defined in the human stomach than in that of the dog. An interesting observation is that this borderline extends much higher along the lesser curvature (above incisura angularis) than it does along the greater curvature.

In the series of 24 autopsy stomachs, 20 could be classed as normal, 2 were believed to show slight evidence of chronic gastritis, while the 2 remaining were rejected because of postmortem degeneration in the 1 case, while the other was complicated by carcinomatous invasion from the pancreas. These specimens were chiefly from individuals of middle age or upward, yet could be classed as essentially normal in over 90 per cent of cases. In our series of 56 surgical stomachs, chronic

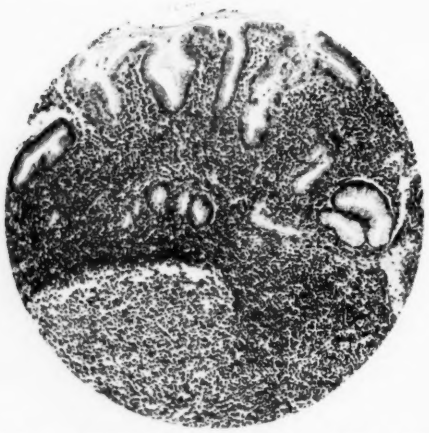

Fig. 3. Chronic follicular gastritis, multiple chronic ulcers, gastric and duodenal. Widespread infiltration of chronic inflammatory cells. Glands active, with layer of mucus on surface. One hyperplastic lymph follicle.

follicular gastritis was diagnosed in 37, or 66 per cent, while chronic gastritis was found in 18 cases, or 32 per cent. The remaining case was normal; the operation performed was gastrotomy for feeding purposes in a patient suffering from carcinoma of the larynx.

Stomachs, the site of chronic follicular gastritis, show definite pathological changes, the microscopic picture being most striking. In the gross the most constant finding (2) is a thickening and palpable stiffening of the stomach wall in the pyloric region. Perigastric adhesions may unite the stomach to neighboring tissues, and enlarged, soft, reddish lymph glands are found above and below the pylorus in about 50 per cent of cases. On opening the stomach the mucosa of the pyloric portion is a deeper pink color than usual and is covered by a thick layer of sticky mucus. The mucosal folds are often smoothed out and tiny ulcerations or erosions may be present, frequently made more conspicuous by a surrounding elevation of mucosa. Occasionally the mucous membrane shows areas of atrophy or papillary overgrowth.

Microscopically, the mucosa shows the most marked changes and in mild cases is the only layer of the gastric wall affected. The reaction is predominantly chronic and is localized to the pyloric gland region, stopping rather abruptly in the transitional zone between the pyloric and fundic gland areas. In cases of ulceration in the fundic gland region the adjoining fundic mucosa, chiefly along the lesser curvature, is involved in the inflammatory change which extends throughout the pyloric area as well. The tubules of the gastric glands are separated by numerous chronic inflammatory cells which prove to be chiefly plasma cells in the more superficial portions between the necks of the glands and lymphocytes with varying numbers of eosinophiles in the deeper portions of the mucosa. In about half the cases (6) a marked hyperplasia of the lymphoid tissue (follicular apparatus) is found in the base of the mucous membrane, which may be aggregated into lymph follicles having hyperplastic germinal centers or extend as a continuous layer of lymphoid tissue resting on the muscularis mucosæ. Ragnotti (5) found such lymphatic formations in 26 of 33 cases of gastric and duodenal ulcer. The lymph follicles are round or oval in shape and vary in size, frequently occupying more than half the thickness of the mucosa. The presence of numbers of these follicles warrants the diagnosis "chronic follicular gastritis." The cells of the gastric glands show surprisingly little change, though the glands often undergo atrophy when the cellular infiltration is pronounced. The cells lining the free surface of the mucosa and the necks of the gastric glands are usually very active and distended with mucus, a layer of which frequently bathes the surface of the mucous membrane. Small superficial erosions and tiny ulcers are not infrequent. Areas of local overgrowth of the mucous membrane are sometimes found, and in advanced cases atrophy of the mucosa with cyst formation. In a small number of cases an acute process accompanies the chronic reaction, with the latter usually predominating. As a rule, polymorphonuclear infiltration is confined to the superficial and mid portions of the mucosa, often in relation to small acute ulcers.

The muscularis mucosæ is invariably thickened except in mild cases. It is frequently split into layers, which are separated by the same type of chronic inflammatory cells. The

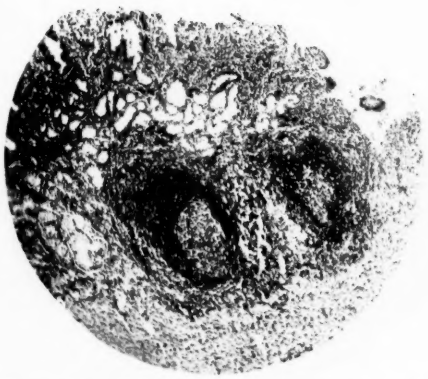

Fig. 4. Chronic follicular gastritis, near gastric ulcer, small. Two large hyperplastic lymph follicles. Edge of ulcer seen at right.

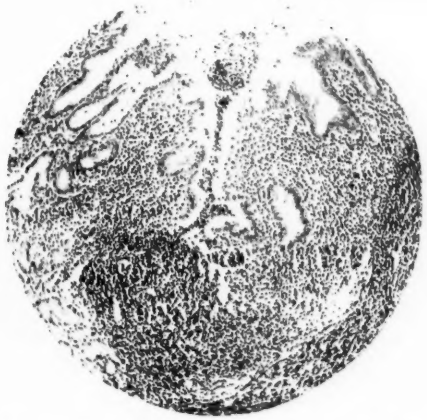

Fig. 5. Chronic gastritis, chronic ulcer and small adenocarcinoma. Early erosion in mucous membrane, leading down to small lymph follicle.

inflammatory reaction commonly spreads into the submucosa, but is much less pronounced, although lymphoid aggregations also occur. Islands of lymphocytes and eosinophiles are occasionally found in the muscle layer and subserosa, usually about a small blood vessel. The blood vessels in the submucosa and subserosa seem increased in number and are often distended. Frequently the inflammatory process is not limited by the pyloric ring, but extends a variable distance into the duodenum.

In our series of 37 cases diagnosed chronic follicular gastritis, it was associated with duodenal ulcer on 18 occasions, with gastric ulcer on 8, gastric cancer on 3, and with stomal or jejunal ulcers in 4 cases. In 4 the condition existed alone. In 1 of these (Case 46) duodenal ulcer had been diagnosed and confirmed by X-ray, but at operation no ulcer was found, while the pylorus was indurated. A second (Case 67) was diagnosed clinically as carcinoma of the pylorus with a filling defect on X-ray, though operation revealed neither cancer nor ulcer. A third (Case 68) was also diagnosed duodenal ulcer prior to operation, with doubtful X-ray findings, but in view of the patient's great pain operation was undertaken and no ulcer found. The fourth (Case 70) had a history suggesting duodenal ulcer for 3 years, but X-ray revealed only a polyposis of the duodenum and no ulcer was found at the subsequent operation or in the pathological specimen submitted.

Of the 18 cases diagnosed in microscopic section as chronic gastritis, duodenal ulcer was associated in 7, gastric ulcer in 4, gastric cancer in 3, and stomal ulcer once. The condition existed alone in 3 cases. In 1 of these (Case 39), the gastritis was very slight, the patient having swallowed a pin some 10 days previously, which was recovered at operation. Another (Case 62) had been diagnosed as gastric ulcer by X-ray 6 weeks prior to operation, but no such lesion could be found. The third (Case 29) was associated with duodenal ileus. In this case there was a doubtful X-ray diagnosis of minute ulcer of pylorus some 6 years previously.

Summarizing, in 56 surgical stomachs, chronic inflammatory changes were found in the wall of all cases except one and in 37 of these lymphoid hyperplasia was a prominent feature. By comparison with the normal stomachs obtained at autopsy, these surgical specimens showed a definite chronic inflammatory change well localized to the pyloric region of the organ. Ringertz interprets this limitation to the pyloric region as the expres-

sion of a special reaction of the mucous membrane in this region to a chronic peptic irritation. In about two-thirds of the present series of cases the gastritis was associated with either duodenal or gastric ulcer, chiefly the former. Most of the remainder were associated with stomal ulcer or gastric cancer. In all of our cases of carcinoma ulceration was present also and in two instances the cancer appeared to be arising in a former chronic ulcer. In 40 cases of gastric ulcer, Sole found an associated gastritis in every one.

The conclusion seems justifiable that chronic gastritis is a definite pathological lesion almost constantly associated with peptic ulcer, gastric cancer, or stomal ulcer. In the present series, 7 cases showed a chronic inflammatory change in the absence of ulceration. Of these, 4 were diagnosed chronic follicular gastritis and had been considered clinically as duodenal ulcer in 3 cases and carcinoma of the pylorus in the fourth. In the 3 cases of chronic gastritis where no ulcer was found, one had been diagnosed by X-ray gastric ulcer, while the 2 remaining cases had a more or less obvious cause for the gastritis. In view of these findings, I believe one must accept that chronic follicular gastritis may exist as a definite entity in the absence of ulceration. This belief is shared by a number of writers (Faber, Fitzgerald, and others). The etiology of the gastritis and its exact relationship to peptic ulcer, whether it be a primary lesion or merely secondary to the ulceration has not yet been definitely established. I am inclined to view the gastritis as a primary lesion and believe that therein lies a fertile field for seeking the origin of the chronic peptic ulcer.

REFERENCES

1. Faber, K. Lancet, 1927, ii, 901–907.
2. Fitzgerald, R. R. Brit. J. Surg., 1931, xix, 25–46.
3. Konjetzny, G. E. Quoted by Lindau and Wulff.
4. Lindau, A., and Wulff, H. Surg., Gynec. & Obst., 1931, liii, 621–634.
5. Ragnotti, E. Centralbl. f. Path., 1932, liv, 58–59.
6. Ringertz, N. Acta path. et microb. scand., 1931, viii, 323–367.
7. Sole, R. Internat. Abstr. Surg., 1931, liii, 546

# CLINICAL SURGERY

*FROM THE UNIVERSITY OF OREGON MEDICAL SCHOOL*

## SEVERING ADHESIONS IN ARTIFICIAL PNEUMOTHORAX BY THE ELECTROSURGICAL METHOD[1]

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PROCEDURES for establishing functional rest of the lung and closure of cavities through lung collapse, or compression, represent a very distinct advance in the treatment of pulmonary tuberculosis. Of the various methods of collapse therapy, artificial pneumothorax is the most valuable, most widely applicable and most extensively employed. It is deplorable that its application is restricted to less than half the cases wherein it is indicated because of pleuritic adhesions allowing either no collapse of the lung at all, or insufficient collapse to provide adequate rest or closure of cavities. An ineffective pneumothorax, caused by pleuritic adhesions, is a common experience to all who employ artificial pneumothorax in the treatment of pulmonary tuberculosis; and the greatest indictment against the method, no doubt, is the persistence with which an ineffective pneumothorax is continued month in and month out (sometimes for years), when clinical and roentgenological evidence clearly shows an unsatisfactorily collapsed lung still a source of tubercle bacilli-laden sputum, fairly constant in its quantity because of an open cavity. In such cases, sooner or later, the disease extends to the opposite lung, intestines or larynx. The case is often then too far advanced for other surgical collapse measures, and the patient is destined to chronic invalidism, facing a certain doom.

According to our experience in over 1,500 cases of pulmonary tuberculosis treated by artificial pneumothorax, 40 per cent of failures in pneumothorax therapy have been caused by pleuritic adhesions which prevented a satisfactory collapse of the lung.

As a result of our observations, we are convinced of the importance of establishing a type of pneumothorax which, within 4 to 6 months, will give the diseased lung sufficient functional rest, collapse, or compression to render it no longer a source of tubercle bacilli-laden sputum, or tuberculotoxæmia.

Stretching adhesions in an effort to secure a satisfactory lung collapse by gradually increasing the intrathoracic pressure, is seldom successful (except when minor adhesions are present) and may precipitate a tear, resulting in spontaneous pneumothorax and empyema. Opening the pleural cavity to cut adhesions is tolerated poorly by tuberculous patients, and the results do not justify the procedure.

If severing adhesions by surgical methods comes into question, undoubtedly the much neglected method of closed intrapleural pneumolysis is the procedure of choice. In selecting the closed method of approach, we have for consideration the method proposed by Jacobaeus in 1913, utilizing the galvanocautery for cutting purposes, or, instead of the galvanocautery, the electrosurgical method, utilizing a high-frequency current, may be used according to the author's technique (7, 8).

The cauterization of adhesions by the galvanocautery is objectionable because of the heat, smoke, pain, and reaction following operation. Perhaps its greatest shortcoming is the character of the cutting produced, as tissue is destroyed a short distance around the cautery; thus, blood vessels are severed without any previous obliteration, unless a dull red heat is used (dark-room control), and undue bleeding may occur. In addition to the danger of bleeding, if too much heat is employed, there is also the possibility of tissue necrosis occurring, which may involve the parenchyma of the lung, tuberculous cavities or tuberculous foci, resulting in spontaneous pneumothorax and empyema.

Because of the obvious objections to the galvanocautery and the success of electrosurgery, especially in brain and cancer surgery, it seemed very probable that this method could be applied intrathoracically with advantage. Several years ago, we began studies of this method, which necessitated the development of technique and instru-

[1]From the Department of Thoracic Surgery, Portland Open Air Sanatorium, Milwaukie, Oregon, and the Department of Medicine, University of Oregon Medical School.

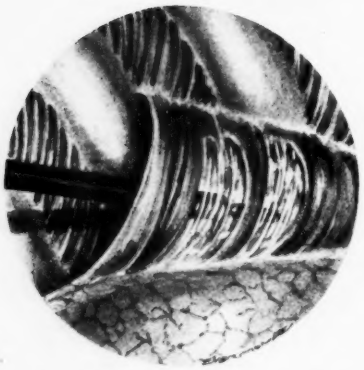

Fig. 1. Arachnoid adhesion showing electrode passed through its meshes. It never contains lung tissue nor blood vessels.

Fig. 2. Three string adhesions of various sizes extending between the partially collapsed lung and chest wall. This type never contains lung tissue nor blood vessels.

ments which now, after 4 years' application, are sufficiently perfected and tested to offer as superior to galvanocautery instruments and method.

In adapting the electrosurgical method of closed intrapleural pneumolysis, the disadvantages of the galvanocautery have been eliminated, and many definite advantages achieved by the use of this more modern and adaptable cutting method.

The indications, contra-indications, and selection of cases for operation have been fully discussed in the author's previous communications.

### PLEURITIC ADHESIONS

Before discussing the operative technique, a brief description of adhesions commonly met with at operation will be given; but no attempt will be made in this compilation to discuss their origin.

A. *Arachnoid adhesions* (Fig. 1). These, when recent, separate readily without cutting. They never contain lung tissue and are not of technical importance.

B. *String adhesions* (Fig 2). These are usually round, but sometimes flat; some are elastic and fragile while others are vascular. As a rule, only a slight increase is seen in their diameter at the chest wall and lung attachments. They are of little clinical importance except when numerous and fibrous.

C. *Cord adhesions* (Fig. 3). This form has the same characteristics as the former group, only they are larger, and while essentially round, at times show ridging. The thoracic wall and lung attachments are often slightly broadened, especially when short, and might be then mistaken for spool or capstan adhesions. They are seldom highly vascular but are of technical importance, as a satisfactory collapse of the lung is often prevented by a single cord adhesion.

D. *Band adhesions* (Fig. 4). These vary greatly in their length, thickness, and breadth. They rarely contain lung tissue but sometimes blood channels of considerable importance are encountered. This type is of great technical importance. Aside from bleeding, severance, which should be made close to the chest wall, is not associated with danger.

E. *Fan-shaped adhesions* (Fig. 5). In this form, small blood vessels are often contained in the free edge. The transition between lung tissue and adhesion is clearly defined. They rarely contain lung tissue and should be severed near the lung attachment. Cutting is not dangerous and a good therapeutic result follows.

F. *Funnel or cone-shaped adhesions* (Fig. 6). This type commonly occurs over superficial cavities, in which case the cavity is often projected into the adhesion. Cutting them, unless around the chest wall attachment, is dangerous.

G. *Spool or capstan adhesions* (Fig. 7). These contain blood channels of marked importance,—also prolongations of cavities. The pulmonary half always contains lung tissue. Although they are less dangerous to cut than the funnel type, they often present the same hazards and should be severed near the chest wall.

H. *Fold and curtain adhesions* (Fig. 8). While frequently appearing as bands on stereoscopic films, giving the impression of being easily cut, they are mostly non-operable, except when thin.

I. *Diffuse adhesions* (Fig. 9). In this type, the lung is densely adherent to the chest wall. They are responsible for more failures in pneumothorax

Fig. 3. Cord adhesions. The somewhat triangular and round type of cord adhesions are shown. Neither contain lung tissue nor blood vessels, but should be severed close to the chest wall instead of in the middle.

than any other kinds of adhesions, and are seldom suitable for cutting.

### THE ELECTROSURGICAL METHOD (AUTHOR'S METHOD)

A detailed description of the physical characteristics of electrical currents employed in electrosurgery will not be given here, as the subject has been well covered by Ward, Clark, and Cushing. However, for the purpose of cutting pleuritic adhesions by the closed method, when hæmostasis by the usual surgical procedure is denied, a brief description of the intrathoracic application is justified.

The cutting effected by the electrosurgical method is not a true cutting, but a molecular disintegration of tissue produced by a high frequency, undamped current—an arc being formed at the point of contact between the tip of the electrode and the tissue. By this method, blood and lymph vessels are sealed, no bleeding occurs and danger of liberating infection from the cut adhesion is infinitely less. There is no radiating heat, no smoke to disturb the view, less pain, and only a very mild reaction after operation.

Intrathoracically, 3 types of current are used to accomplish, first, superficial dehydration; second, coagulation; and third, cutting.

*Superficial dehydration* is seldom used, as the cutting current delivered by the Bovie Unit[1] has sufficient dehydrating properties to prevent bleeding in severing adhesions containing small blood-vessels (up to 2 or 3 mm.)

[1]Manufactured by the Liebel-Flarsheim Company, Cincinnati, Ohio. For the past three years, we have used the Bovie Unit exclusively and found it ideal. Recently, we have used the Bovie Rose Unit and found it satisfactory.

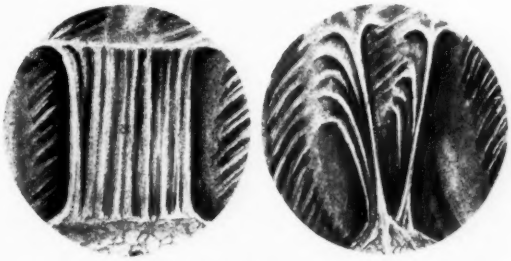

Fig. 4. Two types of band adhesions. They may contain blood vessels but rarely lung tissue, and should be cut at the chest wall attachment.

*Coagulation* is widely employed as a preliminary preparation to the cutting of all adhesions containing, or suspected of containing blood vessels of a moderate size. Coagulation of vascular tissue is the best preparation for cutting, which may be done immediately after coagulation, or, at times, better left to future operations if large blood vessels are seen. Often safe spontaneous separation or stretching may take place, obviating the necessity of a later cutting operation. In an old pneumothorax with a thickened pleura, it is frequently difficult to come to a conclusion regarding the nature of the tissue to be cut. Our procedure in this type of case is to surround the chest wall attachment of the adhesion with a path of electrocoagulation (Fig. 10). After the chest wall has been sealed (24 to 48 hours), reinflations are energetically pursued, and in a short time the coagulated area usually separates, or the adhesion will be seen to stretch out into a slender cord (Figs. 11 and 12).

*Cutting.* The form best adapted for intrathoracic purposes is a current of extreme high frequency with a wave form known as moderately damped. While the degree of dehydration depends to some extent on the cutting surface of the operating electrode (which is quite blunt) and the amount of power, depth, and speed at which the instrument is moved, it depends chiefly on the character of the current or wave form—this may be varied to suit the type of tissue being severed. The greater the blood supply, the greater the degree of dehydration or coagulation that must be used.

### PRE-OPERATIVE PREPARATION OF THE PATIENT

The patient is prepared as for a major thoracic operation. Serous exudate, except when present only in very small quantities, ought to be aspirated a few days before operation, and a pneumothorax refill given at this time (if necessary) to provide as large as possible a pneumothorax in which to

Fig. 5. View of a fan shaped adhesion with base attached to the ribs and intercostal muscles, and rounded apex attached to the lung. Lung tissue is rarely present but may contain blood vessels of considerable size. Should be cut adjacent to the lung attachment.

Fig. 6. Funnel or cone shaped adhesion. This type contains lung tissue and often the prolongations of a cavity and blood vessels; should be cut at the chest wall attachment, if operable. Otherwise, this type of adhesion may be electrocoagulated.

work. If the pleural cavity contains a purulent exudate, it should be washed out with salt solution before operation. In the event of a febrile reaction occurring following aspiration, it is best to postpone the operation until no such reaction follows. If the patient is apprehensive, a mild sedative may be given the night before operation to insure a good sleep, and sputum drainage should be carried out in the morning before operation, so as to prevent excessive coughing during and immediately after operation. Immediately before operation, an injection of pantopon or morphine is usually advisable.

### THORACOSCOPY

Undoubtedly, the most valuable method of determining the possibility of severing adhesions is by thoracoscopic examination of the pneumothorax cavity. The possibility of operation and the degree of success or failure can be determined, in many cases, only by this method: therefore, it should be utilized in any doubtful case, as it is harmless.

The instruments (Fig. 13) required for thoracoscopy are, preferably, an Unverricht thoracoscope[1] with transformer to control its illumination, and a trocar and bakelite cannula[2], by means of which the thoracoscope is introduced through the thoracic wall. After working with numerous thoracoscopes, both direct and indirect, as well as operating thoracoscopes, we believe the Unverricht thoracoscope is the best for general use.

[1]Manufactured by Carl Zeiss, 485 Fifth Ave., New York, N. Y.

[2]Manufactured by Carl McKissick, 425 S. E. 6th Ave., Portland, Oregon.

*Author's trocar and cannula.* The trocar is adjustable to the different lengths of the cannulas. Three different lengths of cannulas are available for use, according to the thickness of the chest wall. The cannulas, of a size to fit the thoracoscope, are made of bakelite, preventing short circuiting of the high frequency current to the chest wall when used with the operating electrodes.

The position of the patient on the table depends upon the operative approach. In most instances, the pneumothorax side will be up (Fig. 14), as most adhesions will be found in the posterior upper quadrant of the pneumothorax cavity. However, the point of entrance of the thoracoscope will depend entirely upon careful study of the stereoscopic films.

We prefer the posterior approach, not only because most adhesions can be more accurately and conveniently studied from here, but also because the intercostal vessels, at this point, lie in the rib sulcus, and are well protected from injury during introduction of the trocar and cannula for the thoracoscope. The anterior approach for the thoracoscope is never used by us except in the case of apical adhesions anteriorly located.

Local anæsthesia for the introduction of the thoracoscope is similar to that for a pneumothorax refill. Caution must be exercised in approaching the pleura, lest the lung be close to the chest wall and punctured. Careful infiltration of the endothoracic fascia is essential. The intercostal space being used is injected with 10 cubic centimeters of 1 per cent novocain suprarenin solution, but there is no need to anæsthetize the intercostal spaces above and below the site of puncture.

Fig. 7. Spool shaped adhesion containing compressed lung tissue and blood vessels. This type of adhesion should not be cut at its narrowest part but at its chest wall attachment, if at all. This type is ideal for electrocoagulation.

Fig. 8. Fold or curtain adhesion. Arises from an interlobar pleuritis. May contain lung tissue and blood vessels. Should be severed (if at all) at the chest wall by transillumination.

It is necessary to make sure that the lung, by chance, is not adherent to the chest wall, or that an adhesion not shown on the roentgen film, is not attached at the point of entrance selected for the thoracoscope. Also, it is important to know whether the lung, if not adherent, is far enough away from the chest wall, or, if an adhesion is present, that it is sufficiently distant to permit manipulation of the thoracoscope. These difficulties are simplified by a preliminary sounding of the pneumothorax cavity with a Solomon catheter through a small cannula introduced through a puncture at the site selected for the thoracoscope (Fig. 15). Next, a 1 centimeter incision is made through the skin, and the trocar and bakelite cannula[1] for the thoracoscope are gently pushed through the chest wall in a horizontal direction. The outer end is depressed and the tip of the instrument directed upward, thus avoiding the trickling of blood down the shaft of the cannula, which might later foul the lens. Care must be taken to avoid suddenly plunging the trocar through a thickened pleura that offers considerable resistance.

The room is then darkened, the trocar withdrawn from the cannula, and the thoracoscope introduced in a horizontal direction, with the lens up. A general survey of the pneumothorax cavity is made, followed by a careful study of the adhesions which should furnish complete orientation regarding their position and direction with relation to the chest wall and collapsed lung, as well as their dimensions, configuration and type. It is particularly essential to know how close the point selected for cutting is to large blood vessels or important nerve trunks. The presence of lung tissue, blood vessels, and tuberculous deposits in the adhesions to be cut should be determined; following this, a study is made of the inner chest wall, and a site selected for entrance of the operating electrode—one that will give an unobstructed view and permit placing the cutting instrument in the most advantageous position across all important adhesions at a proper angle for the purpose of cutting, and avoid introducing the electrode at a point where adhesions prevent its being seen, as, for instance, on the blind side of adhesions.

[1]The author uses a bakelite cannula for the thoracoscope instead of the Unverricht ball-valve type because it permits an interchange of instruments; moreover, the ball-valve cannula is unnecessary as the intrathoracic pressure is equalized the moment the cannula for the operating instrument is introduced.

Fig. 9. Diffuse adhesion. The parietal and visceral pleura are intimately fused; lung tissue extends to the chest wall; blood vessels are abundant. Complete severance should not be attempted.

Fig. 10. Deep puncture coagulation of the chest wall attachment of a spool adhesion, showing electrode and line of coagulation. Insert, Pointed operating tip penetrating the chest wall attachment for deep coagulation.

### ELECTROSURGICAL CUTTING

The instruments required for the electrosurgical method of cutting adhesions, aside from the electrosurgical unit, are: the operating electrodes, extensions and operating tips for the electrodes (Figs. 16 and 17). These instruments and their manipulation have been fully described previously (8), and full instructions are furnished by the manufacturer.

The point of entrance of the electrode will depend entirely upon the thoracoscopic findings. Since, in the majority of cases, the thoracoscope will be most advantageously introduced at the angle of the scapula, the anterior axillary line will prove a very suitable place for introducing the electrode—the intercostal spaces being wide and permitting a greater degree of manipulation of the instrument; furthermore, the relative position of the two instruments is very satisfactory. The area to be entered on the chest wall is controlled by making gentle pressure upon the intercostal space with the index finger of the free hand on the external surface—one then observes the result through the thoracoscope: if accurately located, the operator will observe, unless the pleura is very thick, a circumscribed bulging of the intercostal space as downward pressure is exerted by the finger (Fig. 18).

After suitable infiltration of the site determined upon for introduction of the electrode, the infiltrating needle is passed into the pneumothorax cavity and observed through the thoracoscope. The needle is then withdrawn sufficiently to allow careful infiltration of the pleura and endothoracic fascia. This area may be observed through the thoracoscope as a blanched one. Through a small skin incision, the trocar and cannula for the operating electrode are introduced in the same manner as that of the thoracoscope. Here, however, the maneuver is controlled by the thoracoscope.

After inserting the cannula for the thoracoscope, as described, the electrode is introduced and placed upon the adhesion. Decision as to the point where the adhesion is best cut will depend upon its type and its relationship to important structures.

In proceeding to sever the adhesion, one should bear in mind that the closer the cutting is to the chest wall, the greater will be the pain and danger of bleeding, inasmuch as sensation comes from the intercostal nerves, and the blood supply of adhesions is derived, mostly collateral, from the intercostal vessels. On the other hand, division near the lung, while painless, is dangerous, because one may open into a prolongation of a cavity projected within the adhesion or into compressed lung tissue and, in either event, precipitate a spontaneous pneumothorax or liberate infection—almost certain to result in empyema.

The beginner will do well to confine himself to string, cord, and small band adhesions; the spool, funnel, and curtain types should be avoided. It must be a fixed rule never to cut any tissue until the operator is perfectly familiar with its structure.

TABLE 1*.—COMPLICATIONS AFTER OPERATION INCLUDING THE GALVANOCAUTERY AND AUTHOR'S METHOD—249 CASES

| | No. | Per Cent |
|---|---|---|
| Serous exudate | 63 | 25.7 |
| Purulent exudate | 41 | 16.5 |
| Hæmorrhagic exudate | 26 | 10.4 |
| Febrile reaction | 7 | 2.4 |
| Severe hæmorrhage | 3 | 1.2 |
| Bronchopleural fistula | 4 | 1.6 |
| Spontaneous pneumothorax | 1 | .4 |
| Severe postoperative vomiting | 1 | .4 |
| Gas embolism | 0 | |
| Shock | 0 | |
| Severe surgical emphysema | 0 | |

*This table comprises complications occurring in 136 patients operated upon with the galvanocautery and 113 operated upon by the author's method. However, in 35 of the latter group, an obsolete high frequency apparatus was used, while in 78 cases the Bovie unit was employed.

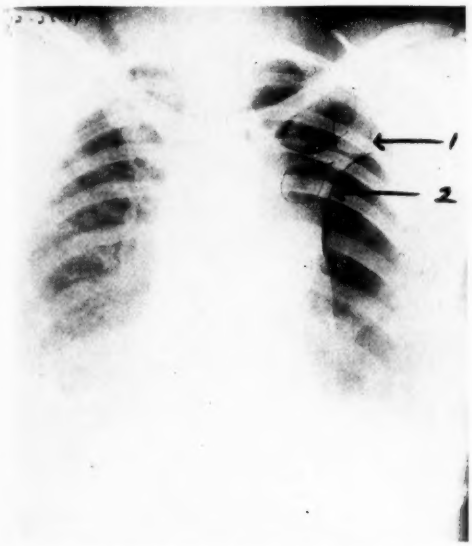


Fig. 11 (retouched). Cone shaped adhesion preventing collapse of a cavity, *2*, which is prolonged into the adhesion. *1*, Shows the chest wall attachment after electrocoagulation. The configuration and size of this cavity had remained unaltered by a pneumothorax in the previous 3 months.

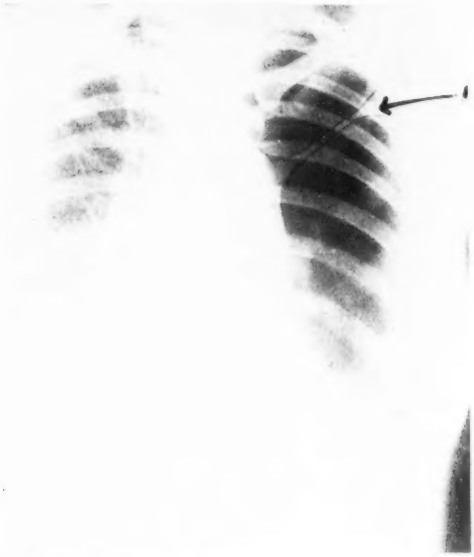


Fig. 12 (retouched). The same case 1 month later. The cavity is completely closed.

After the adhesion has been completely cut through, a careful examination is made for bleeding, which must be arrested by application of the coagulation current. If bleeding has taken place, the pleural cavity should be washed clean with salt solution.

The operator, having satisfied himself that everything is in order within the pneumothorax cavity, the instruments are withdrawn and the incision closed with a single gut suture.

The patient is emphatically warned against coughing. A small roll of one-inch gauze bandage for compression is held firmly over the site of the puncture and this is covered with strips of three-inch adhesive plaster, extending well to the front and back.

TABLE II.—COMPARATIVE FREQUENCY OF EXUDATE FORMATION FOLLOWING VARIOUS OPERATIVE METHODS—249 CASES

| | Jacobaeus method | | Author's method | | | |
|---|---|---|---|---|---|---|
| | Galvanocautery, 136 cases | | Unnamed high frequency unit 35 cases | | Bovie high frequency unit 78 cases | |
| | No. | Per cent | No. | Per cent | No. | Per cent |
| Serous exudate | 28 | 20.5 | 11 | 31.4 | 3 | 3.8 |
| Purulent exudate | 36 | 26.4 | 4 | 11.4 | 2 | 2.5 |
| Hæmorrhagic exudate | 14 | 10.3 | 11 | 31.4 | 1 | 1.2 |

### POSTOPERATIVE CARE

The postoperative care consists in absolute bed rest, with the side operated upon up for the first 24 hours. Cough should be controlled during the first 24 to 48 hours with codeine, dionine, or even morphine, if necessary. Bed rest is maintained for a minimum of 7 days. Straining at stool and physical efforts, including excessive laughter, are prohibited.

The strictness and duration of the postoperative care, before the case reverts to the medical service for continuance of pneumothorax treatment depends upon the character of the operation and the patient's reaction. As a rule, the postoperative course, following electrosurgical cutting, is mild: at times, a temperature of 99 to 100 degrees F. may last but a few days. Postoperative pain, if any, is slight and easily controlled with codeine.

After 24 to 48 hours, a roentgen film should be made, and the time and quantity of gas reinflation decided upon. The intrapleural pressure usually will be less than before operation. Positive pressures must be avoided, when possible; but, should thick walled cavities be present with thickened pleura, it may be necessary to resort to positive

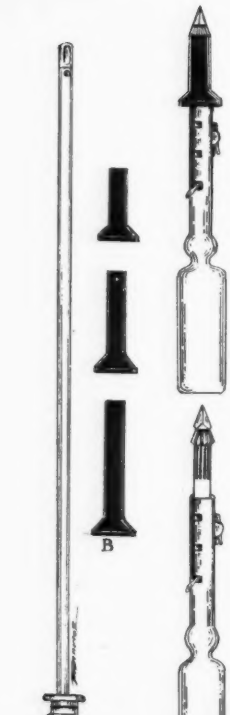


Fig. 13. *A*, Unverricht thoracoscope. *B*, Three lengths of bakelite cannulas. *C*, Author's adjustable trocar.

Fig. 13.

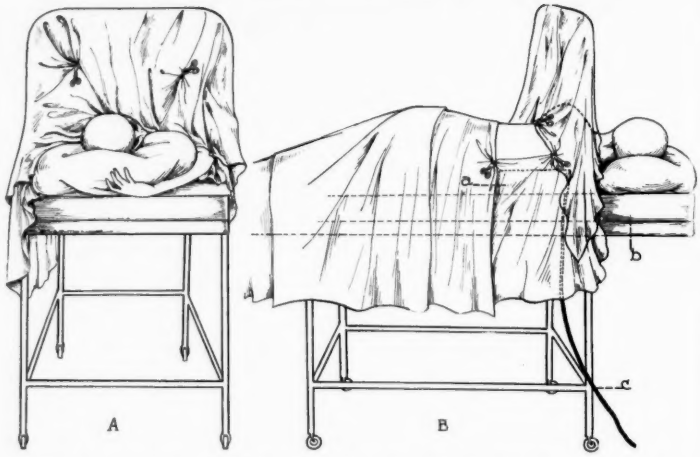


Fig. 14. Position of patient on operating table for an intrapleural pneumolysis on the left side. *A*, Anterior view, showing the manner of draping the sterile sheets; the position of the head and arms of the patient is also shown. *B*, A sheet of diathermy metal, *a*, is placed beneath the patient and connected with the electrosurgical unit by a cable, *c*. The patient rests upon a cellular rubber pad, *b*.

pressures to secure closure of offending cavities. If cavity drainage is interfered with, and sputum retained, it may be necessary to aspirate air and slightly expand the lung to establish drainage, following which, frequent refills with smaller quantities of sterile air should be carried out until a satisfactory collapse is established and the patient rendered sputum-free. Reinflation is carefully controlled by the X-rays, and, for the first few inflations, a roentgenogram should be made, if possible, after every air injection.

Barring complications, the sanatorium patient may be back on the pre-operative routine in 1 to 2 weeks. Ambulant and working patients, admitted for operation, are individualized regarding their routine.

### COMPLICATIONS

The complications after operation, in our entire series of 249 cases, are shown in Table I. But it should be pointed out that the first 136 cases were done with the galvanocautery, and of the remaining 113 cases, 35 were performed with an unnamed high frequency machine which provided a cutting current, yet possessed no dehydration qualities; whereas, the last 78 cases were operated upon with the Bovie unit. Table II shows the marked reduction in exudate formation incidence following use of the Bovie unit. It should be mentioned that of the three instances of severe hæmorrhage, one occurred during use of the galvanocautery and 2 during operation with the unnamed high frequency machine. The single instance of spontaneous pneumothorax occurred on the contralateral side 7 days after operation; it was due to an asthmatic paroxysm and was fatal. This case represents the only fatality in the entire series, directly or indirectly due to operation.

### RESULTS OF TREATMENT

During the past 7 years, 311 operations have been performed on 249 cases (Table III). In 211 cases, a single operation was done, in 22 cases, 2; and 10 cases had 3 operations; 4 cases had 4 operations, and 2 cases had 5 operations each.

In estimating the value of the operation, it must be borne in mind that the purpose of the operation is to convert a useless, or unsatisfactory, pneumothorax into an efficient one. Accordingly, the results of operation have to do, primarily, with the number of unsatisfactory pneumothorax cases which were converted into satisfactory ones, and

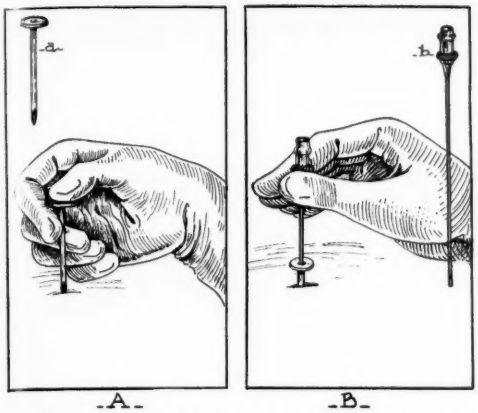


Fig. 15. Method of palpating for the lung and nearby adhesions to determine whether site is suitable for introduction of the thoracoscope. *A*, Introducing the cannula, *a*. *B*, Introducing the Solomon blunt needle, *b*.

remotely to the end-result of the pneumothorax thus established. Every case classified as "clinically and technically successful" from the standpoint of the operation, means that complete severance of all adhesions was effected, followed by a satisfactory pneumothorax with prompt (sometimes immediate) disappearance of severe cough and expectoration.

Of the 249 cases, 152, 61 per cent, were technically and clinically successful. Of these, 32 cases had to deal only with string and cord adhesions. In 85 cases, band adhesions alone were present; in 18 cases only fold adhesions, and in 4 cases, all three types of adhesions were present.

The technically unsuccessful but clinically successful group comprises 19 cases presenting all the above types of adhesions, as well as others described under the classification of "adhesions." This group embodied cases wherein some adhesions, because of their character, were left uncut, yet sufficient collapse of the lung was obtained to bring about a satisfactory clinical result by electrocoagulation.

It has been pointed out that clinical success is not always dependent upon cutting all adhesions. A determination as to the ones of technical importance should be made and only these severed. Those unimportant technically, if of an unfavorable type for operation, should not be molested. Of the 249 cases forming a basis of this study, 172, 70 per cent, obtained a clinically successful result.

The technically successful but clinically unsuccessful cases were two; one of these, previously quoted, died of a spontaneous pneumothorax 7

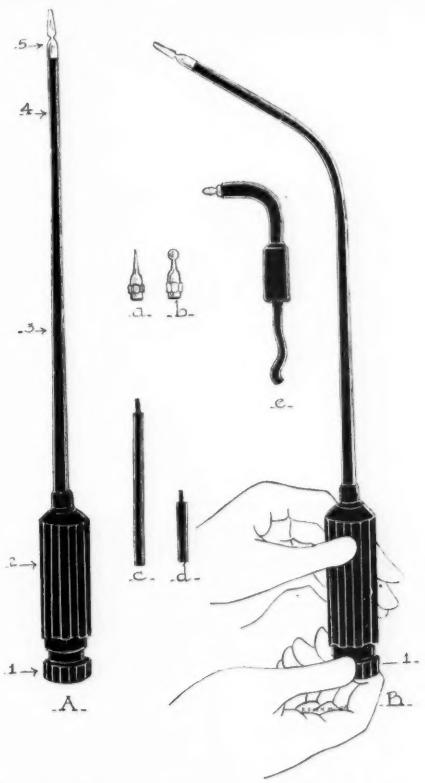


Fig. 16. Author's flexible electrode. *A*, The instrument straight. *1*, Fluted disk for flexing instrument. *2*, Hand grip. *3*, Hard rubber shaft, except distal one-fourth which has a soft rubber covering. *4*, Medium shaft extension. *5*, Operating tip. *B*, The instrument flexed by turning disk, *1*. *a*, Pointed tip for cutting and deep coagulation. *b*, Coagulating tip. *c*, Long shaft extension. *d*, Short shaft extension. *e*, Connection with unit which fits in the shaft of the hand grip.

days after operation, and the other of sudden profuse hæmorrhage from the successfully collapsed lung (24 hours after operation), which, due to her position, with the pneumothorax side up, filled the dependent sound lung. This patient had profuse bleeding from an open cavity before operation; the operation was planned to effect closure of the cavity. The technically and clinically unsuccessful group comprises 76 cases; 40 of these presented only fold adhesions and 34 had fold adhesions in combination with others of the string, cord or band type. These latter were severed; but the remaining fold adhesions prevented a satisfactory collapse of the lung.

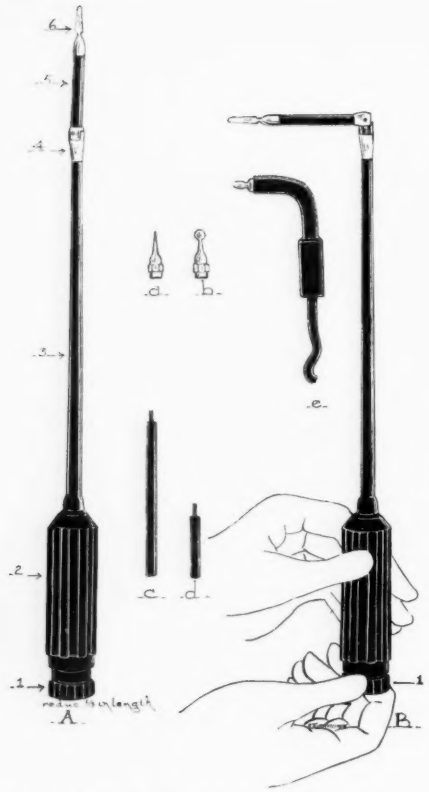


Fig. 17. Author's jointed electrode. *A*, The instrument straight. *1*, Disk for angulating the instrument. *2*, Hand grip. *3*, Hard rubber shaft. *4*, Metal joint. *5*, Medium extension. *6*, Operating tip. *B*, The instrument angulated by turning the disk, *1*. *a*, *b*, *c*, *d*, and *e*, the same as in Figure 16.

The remote results, in the cases operated upon, are shown in Table III. Of the 152 technically and clinically successful ones, 120 were bed cases and 32 were ambulant before operation; 146 cases had a positive sputum; in 6, it was negative. All these latter 6 were patients who had been under satisfactory pneumothorax, but the adhesions were contracting and causing an early lung expansion. These cases had been under observation for 5 years, during which time pneumothorax treatment was continued for at least 2 years. Eight more recent ones are still bed cases; 18 are ambulant, and 126 are working—all have a negative sputum. Of the 19 technically unsuccessful but clinically successful ones, all were bed cases, and all had tubercle bacilli in their sputum. Four

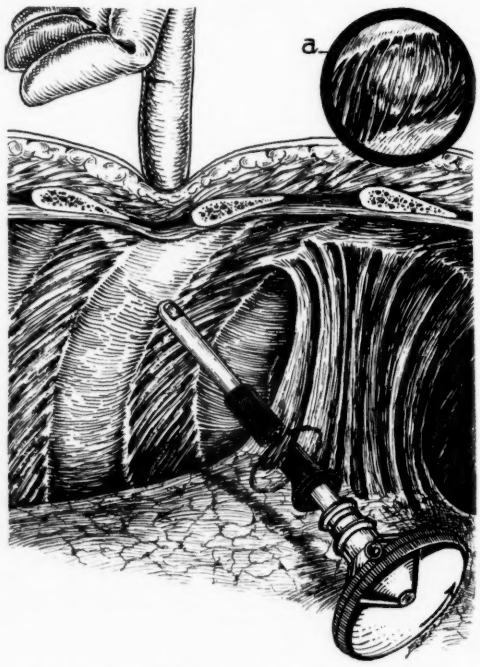


Fig. 18. Method of selecting the site for introducing the operating electrode through the chest wall. *a*, Thoracoscopic view showing elevation produced by pressure of the finger.

years after operation, 7 are ambulant and 12 are working. All have a negative sputum.

## CONCLUSIONS

It is unjustifiable to continue an unsatisfactory pneumothorax over a prolonged period, because of the danger of extensions of the disease to the opposite lung, to the gastro-intestinal tract or to the larynx. Our experience covering the past 20 years, and including over 1,500 cases of artificial pneumothorax, has demonstrated that intrapleural pneumolysis under thoracoscopic guidance will convert approximately 70 per cent of unsatisfactory cases of pneumothorax into satisfactory ones. We have shown that less than 15 per cent of recoveries take place as the result of the continuation of an unsatisfactory pneumothorax, and that serious dangers attend the use of high intrapleural pressures in an attempt to stretch adhesions. If the adhesions prevent a satisfactory collapse of the lung, after a probation of 4 to 6 months, it is very improbable that a satisfactory end-result will be obtained by further continua-

TABLE III.—INTRAPLEURAL PNEUMOLYSIS REMOTE END-RESULTS OF OPERATION—249 CASES

| Result of operation | Cases | Condition before operation | | | | Present condition | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Bed | Amb. | Sputum Pos. | Sputum Neg. | Bed | Amb. | Wk.* | Sputum Pos. Neg. | |
| Technically and clinically successful | 152 | 120 | 32 | 146 | 6 | 8 | 18 | 126 | 152 | Working 83 per cent |
| Technically unsuccessful, clinically successful | 19 | 19 | | 19 | | | 7 | 12 | 19 | Working 68 per cent |
| Technically successful, clinically unsuccessful | 2 | 2 | | 2 | | | | | | Two dead: 1 from spontaneous pneumothorax after operation: 1 from hæmorrhage opposite lung. |
| Technically and clinically unsuccessful | 76 | 62 | 14 | 76 | | This group comprised cases presenting adhesions unsuited for operation. In most cases minor adhesions of no technical importance were severed. In all appropriate cases patients were subjected to other operative collapse procedures. The end-result is not attributable to the pneumolysis—consequently not recorded here. | | | | |

*Wk.—Working.

tion of the pneumothorax. After a trial has been given, an unsatisfactory pneumothorax should be converted into a satisfactory one by intrapleural pneumolysis. If this is impractical, other surgical collapse methods should be utilized.

The electrosurgical method is superior to the galvanocautery and the operation is not dangerous when properly performed. Our mortality was 1.5 per cent in 249 cases, including the use of both the galvanocautery and the electrosurgical method. This single operative mortality was only indirectly due to the operation.

## BIBLIOGRAPHY


1. CLARK, W. L. Cancer of the oral cavity, jaws and throat. J. Am. M. Ass., 1918, lxxi, 1365.
2. Idem. Chapter on Desiccation and Coagulation. Keen's Surgery 8.
3. Idem. Electrothermic methods in treatment of neoplastic and allied diseases. J. Am. M. Ass., 1926, lxxxvi, 595.
4. CLARK, W. L., ASNIS, E. J., and MORGAN, J. D. Clinical and histological observations in the treatment of neoplastic diseases by combined methods. Atlantic M. J., 1923, xxvii, 541.
5. Idem. Electrothermic methods in the treatment of neoplastic lesions, etc. Radiology, 1924, ii, 233.
6. CUSHING, H., and BOVIE, W. T. Electro-surgery as an aid to the removal of intracranial tumors. Surg., Gynec. & Obst., 1928, xlvii, 751.
7. MATSON, RALPH C. The cauterization of adhesions in artificial pneumothorax by the Jacobaeus-Unverricht method of closed pneumolysis. Am. Rev. Tuberc., 1929, xix, No. 3.
8. Idem. Operative collapse therapy in the treatment of pulmonary tuberculosis. Western J. Surg., 1930, November and December; 1931, January.
9. WARD, G. E. Value of electrothermic methods in the treatment of malignancy. Am. Rev. Tuberc., 1925, lxxxiv, 660.
10. Idem. The efficient method of hemostasis without suture. Med. J. & Rec., 1925, cxxi, 470.

# THE PRE-OPERATIVE TREATMENT OF PROSTATIC OBSTRUCTION

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THE greatest advance to be made in the treatment of prostatic obstruction at present concerns the pre-operative care. Investigation will show that this part of the treatment of these conditions is associated with a much higher mortality rate than is the actual operation itself, irrespective of what method is used, and is responsible for the high morbidity which is entirely unnecessary. It would seem that very little improvement can be made in the operative mortality rate. My own statistics show that in performing Young's perineal prostatectomy for benign hypertrophy the mortality has been reduced to 0.7 of 1 per cent in patients under 80

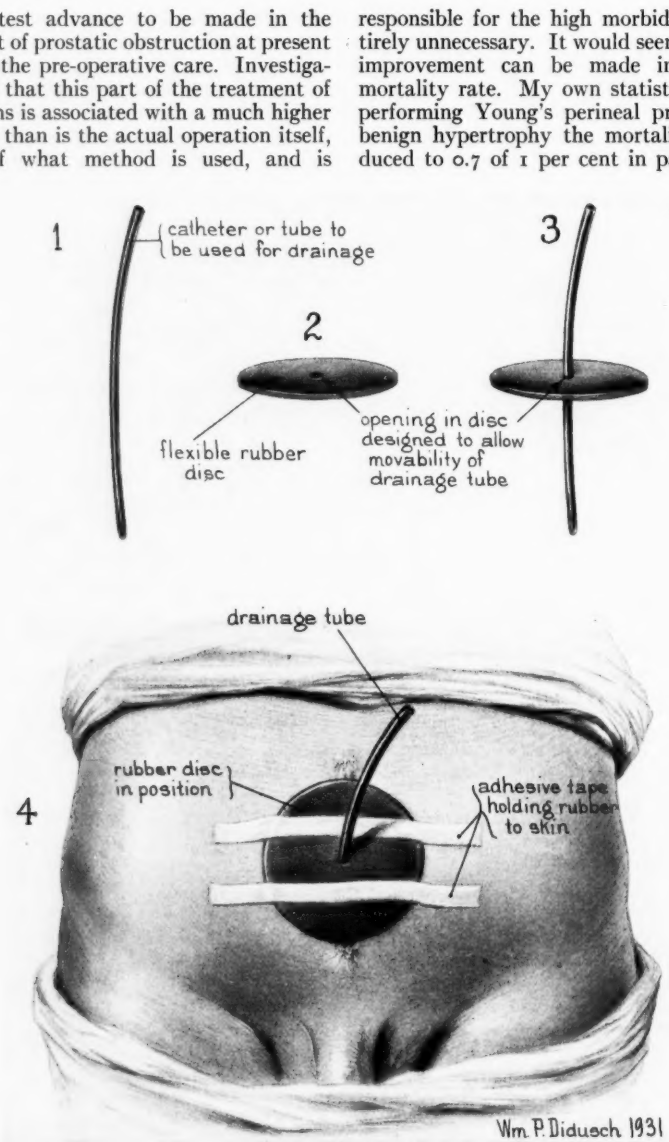


Fig. 1. Author's suprapubic drainage apparatus.

years of age. I would repeat that advances in curability must come from improvement in the pre-operative technique. Pre-operative preparation has long been recognized as a necessary adjunct in the large majority of cases of prostatic obstruction and should be very definitely standardized and perfected. I am convinced that the present method of handling cases of prostatic obstruction before operation is entirely wrong in the large majority of instances, is extremely harmful as carried out, and is directly responsible for both a high pre-operative and postoperative mortality rate and an unnecessarily long morbidity.

When I first began the practice of urological surgery, practically all patients with prostatic obstruction were treated before operation either by means of a retention catheter or suprapubic drainage, and these same procedures are used today—no improvement has been made in recent years in either of the procedures. The death rate associated with suprapubic drainage is not negligible, particularly in our large free clinics. Prolonged morbidity and an occasional death, however, not infrequently can be attributed to various complications associated with retention catheters.

At one time I made the statement that prostatic surgery should be removed from the realm of emergency surgery where it had been put not only because of the fear of operation that these patients had but in addition because the medical adviser had suggested that nothing be done. Added to this was the advice of the surgeon, for few of us cared to operate in the early stages of prostatic obstruction before the patient had residual urine and when he seemed to be in perfect health except for prostatic irritation, difficulty in urination, or frequency of urination. Hence the condition was allowed to ripen and during this period patients suffered considerably; gradual deterioration of the body took place, and usually the patient had to have emergency treatment.

Undoubtedly, the greatest advance that has recently been made in the treatment of prostatic obstruction has been the development of various intra-urethral methods of operating. The wide dissemination of knowledge in regard to these operations has enlightened patients suffering from prostatic obstruction and has caused them to seek the advice of a specialist as to the best method of treatment. This factor has done more than any other to remove these cases from the realm of emergency surgery. Resectoscopy can certainly be carried out with satisfactory results in all cases of Types 1 and 2 of prostatic obstruction. It may be possible to make it a satisfactory procedure in Type 3. It is the method of choice in many cases of carcinoma and of all bar formations. Resectoscopy is a fairly simple operation although it requires the utmost technical skill. It is an operation to be performed only by one highly trained as a cystoscopist, who thoroughly understands the pathology of the prostate, and who has had thorough training and experience in urology.

As statistics have accumulated to show the relatively benign nature of resectoscopy and of perineal prostatectomy, patients now come for operation more often at the early stages of the disease rather than late when they are in need of an emergency treatment and their kidneys are completely damaged. The patients, therefore, are in much better condition to withstand operation. Many of them have only frequency or difficulty in urination, do not have large amounts of residual urine, and present no considerable damage to the kidneys or the various systems of the body. We have learned our lesson *too* well, however. We had learned that when preliminary treatment of prostatic obstruction was not carried out operation was not infrequently followed by seemingly unexplainable complications and death. Preliminary treatment therefore not only was given to patients with large amounts of residual urine, but it became our custom to use it in all cases of prostatic obstruction irrespective of whether the kidneys were damaged or not, or as to whether or not there was residual urine. The first thing then that I would discuss in regard to the treatment of prostatic obstruction is whether preliminary treatment should be carried out in a case in which, for instance, residual urine is slight, the bladder is not markedly infected, and the kidney function is normal, yet operation is indicated because of irritation or other symptoms of prostatic hypertrophy or bar formation in which diverticula are not present, the bladder does not show marked evidence of trabeculation, and there is no deterioration of renal function. There is certainly no reason to catheterize a man who can empty his bladder. There is certainly no reason to put in a retention catheter to be followed by infection not only of the entire urinary tract including the urethra but also of the seminal tract, prostate, seminal vesicles, and, unless vasoligation is done, of the epididymides. In doing a relatively large number of perineal prostatectomies I have noted these differences: (1) If a retention catheter has been used, when the rectum is stripped back along the fascia of Denonvillier the posterior surface of the prostate is redder than usual. The two layers of the fascia of Denonvillier

are often much more adherent, and when the prostate is incised one much more frequently encounters purulent exudate. The tissues along the cut also show increased redness. (2) If intermittent catheterization is carried out these conditions are found far less frequently. In some instances in which a retention catheter has been used, I have found not only relatively large collections of pus within the prostate itself but in a few cases large quantities of pus collected back of the bladder in the region of the seminal vesicles. Many of the rises in temperature heretofore attributed to renal infection have undoubtedly been due to such infection, but in a number of cases the rises in temperature have been caused by infection of the genital tract. I have seen patients in whom marked arthritis has developed while a catheter has been in place, but the inflammation immediately subsided when the catheter was withdrawn. I have seen patients in whom the absorption has been so great from the retention catheter that the patients ran high temperatures and life itself was in danger. All symptoms subsided when the retention catheter was removed and the patient was intermittently catheterized. I do not subscribe to the idea that infection of the genito-urinary tract is of value in producing a protective immunity; my opinion is that all infection should be avoided as far as possible.

I would now discuss those cases in which the patient has residual urine and needs preliminary treatment. In these cases heretofore either a retention catheter or suprapubic drainage has been used. I shall refer particularly to the cases in which prolonged drainage is not necessary but in which restoration of function is important. In this type of case neither suprapubic drainage nor a retention catheter should be used, provided perineal prostatectomy or resectoscopy is to be done. I will not discuss the value of walling off the suprapubic space where suprapubic prostatectomy is contemplated as my experience does not make me an advocate of suprapubic prostatectomy. These patients should be treated entirely by intermittent catheterization. A retention catheter should not be used for it will surely set up a prostatitis and aggravate a renal infection that may be present or produce one if not present, and this risk is too great for the simple matter of withdrawing urine every 2 hours. It is not necessary to put these patients to bed. They are best treated as ambulatory patients, by competent nurses.

Like many things, intermittent catheterization is easier said than done. Who is going to do it? The internes in our modern hospitals are certainly too much engaged with their general routine duties to look after the catheterization of even a single patient to say nothing of the varying needs of many cases of prostatic obstruction. It requires considerable skill to catheterize some patients. In my private practice I have solved the problem by having well trained female nurses take care of this work. The nurses are especially trained in the work and they have proved to be a tremendous relief to me and of inestimable benefit and comfort to the patients thus cared for. I am sure that, if he stopped to think, no physician would tolerate having a catheter fastened into the urethra of a patient or subject him to unnecessary suprapubic drainage simply because the interne was too busy, the attending man not at hand, the orderlies inexperienced, and the nurses averse to caring for such patients.

The pre-operative treatment of patients with prostatic obstruction calls for complete reorganization of the routine now practiced in the urological wards; such reorganization would be of more value to the large free clinic than to private hospitals. Nothing could be more revolting than to see in our public and private institutions men able to be up and walking about the wards who have fastened to them retention catheters reeking with pus. Would it not be far better technique to have taught these patients in the Out-Patient Department how catheterization is carried out? They could easily have been made to realize the moderate degree of cleanliness necessary and that such cleanliness far surpasses the use of any type of retention catheter. Furthermore, the patients can remain at home while treatment is being carried out. Of course, there are many indigent patients who require hospitalization because they are totally unable to care for themselves and have no homes. Others come long distances for treatment and must be cared for in the hospital. In such cases the morbidity at present is tremendously increased by suprapubic drainage and retention catheters and the cost to the clinic is much more than would be the cost of a sufficient number of competent nurses to carry out catheterization.

For a number of years it has been my custom to teach certain patients how to care for themselves at home and after office observation for a certain period to operate upon them the day after they are admitted to the hospital. Somewhat similar methods could be carried out at our large public institutions and the saving would be tremendous. I wish to make it clear, however, that the saving of expense is not the primary reason for my advocating this method. I do believe, however, that the method is associated with higher surgical

idealism. At present patients are confined to bed and subjected to infection and considerable discomfort who could be up and about enjoying life and still have the proper care without being subjected to the measures which are undoubtedly the most trying part of the treatment of prostatic obstruction. When it is necessary that for any reason patients must remain in the hospital—the large private or public hospital—I would suggest that a catheterization station be set up in the hospital and competent nurses on duty constantly night and day be put in charge of this station. The patients should be instructed to report to this station every 2 to 3 hours during the day, according to his surgeon's directions, or at any time when he is uncomfortable. At night catheterization should be carried out at the bedside at intervals best suited to particular cases.

I shall next discuss those cases in which the amount of residual urine is large. It has been suggested that the large amount of residual urine should be gradually withdrawn. With this idea I differ entirely. I have seen no evidence of harm when the entire amount is immediately withdrawn; on the contrary, I have seen the greatest relief, comfort, and benefit follow the withdrawal of the entire amount. When the entire amount of urine is withdrawn, I have found it advisable to instill into the bladder 20 cubic centimeters of 1:500 silver nitrate, to combat infection. The patient should be put immediately on urotropin and his blood pressure and heart action should be watched. If he has been up and around, he should stay up and around and water should be forced. In very sick patients requiring immediate rest in bed, the giving of 500 cubic centimeters of glucose solution intravenously morning and night, with heart stimulants, is of great value. Some of these patients are so saturated with water as to require catheterization at 1 hour intervals. I recall a case in which over a period of 8 hours I withdrew 9000 cubic centimeters of urine in four catheterizations. In this case the patient had been fastened to a gradual decompression apparatus for about 20 hours. He had developed cardiac disturbances and beginning œdema of the lungs. This rapidly cleared up upon the immediate complete evacuation of the bladder and by continued evacuations of urine by repeated catheterization of the bladder at short intervals. For this type of case it has been recommended that there be inserted a retention catheter attached to a tube which is raised to such height as will balance the bladder pressure and that the tube be gradually lowered over a fairly long period of time, thus gradually decreasing the urinary pressure. Patients who have such large amounts of residual urine should certainly not have catheters fastened into the urethra. The question is not entirely a mechanical one but is as well a biological one; the probable infection, both of the prostate and of the urinary tract, associated with the retention catheter would far outweigh any benefits that might result from gradual decompression even if this method of treatment were correct, and I do not believe it is. I have at various times done a nephrostomy upon a completely blocked remaining kidney. In no instance have I ever found that the immediate removal of pressure has done anything except the greatest good, and I am sure that immediate bilateral decompression such as takes place following catheterization of the bladder in overdistention is not associated with either renal hæmorrhage or anuria. The hæmaturia encountered is usually due to damaging catheterization and, if anuria occurs, it is due to some other cause than the withdrawal of urine.

As infection is associated with all types of preliminary treatment, it is my opinion that it is valuable to combat the infection from the beginning. I have found that careful catheterization and the use of urinary antiseptics by mouth and the use of instillations of 1:500 silver nitrate into the bladder at each time of catheterization, have been most helpful in combating infection. In some instances it is advisable to start with 1:1000 silver nitrate.

In many instances I believe that suprapubic drainage is advisable; in the very ill person whose kidneys have been badly damaged, whose whole system is considerably run down, and who requires drainage over a long period of time. It may be that it will not be possible to build up his kidney efficiency beyond a certain point, say 7 per cent phthalein in 2 hours, but this does not mean that it will not be possible to build up the patient's general resistance so that he will be able to stand a prostatectomy, if he has prolonged drainage. In these very ill patients, with high blood nitrogen and low phthalein, after intermittent catheterization over a period of time, I believe that it is a valuable thing to introduce a suprapubic drainage tube and allow these patients to return to their homes for from 3 to 6 months when they should return to the hospital for any type of prostatic surgery that seems advisable. For this type of drainage I have devised a tube which is shown in Figure 1. This apparatus permits the patient himself to adjust the depth of the tube and to remove it for boiling and cleaning. I have found this tube valuable both for suprapubic and for nephrostomy drainage. Pezzer catheters are

difficult to get out, and are, therefore, not often cleaned. They are apt to break off, to collect lime salts, and to harbor infection. The tube which I have devised and have previously described is easily removed without pain, the depth can be adjusted exactly, and the patient can sterilize it every day.

### SUMMARY AND CONCLUSIONS

With the development of resectoscopy and the education of the medical profession in general as to the benign nature of prostatic surgery, many patients with prostatic obstruction now present themselves for treatment much earlier than formerly, and in many of these patients it is advisable not to carry out any type of preliminary treatment whatsoever in the way of drainage. In those patients requiring preliminary treatment who heretofore have been treated either by retention catheter or by suprapubic drainage the morbidity rate and the mortality rate can be considerably lowered by the routine use of intermittent catheterization. In my opinion there is no justification in this large group of cases for either suprapubic drainage or retention catheter and in this group both of these procedures should be abandoned. If the retention of urine is great, heretofore it has been believed that gradual decompression is advisable. I do not agree with this; I believe that the fastening in of a retention catheter is a dangerous procedure. I further believe that retained urine should be immediately withdrawn and that immediate stimulation of the kidneys should be carried out, by supportive measures of the heart and, in some instances, by intravenous injections of fluids. I believe that infection associated with the preliminary treatment is a harmful thing and that it should be combated by antiseptics by mouth and by instillations of antiseptics through a catheter. In certain types of cases the patients will better withstand prostatic surgery after intermittent catheterization and suprapubic drainage for a relatively long period of time in spite of the fact that in many instances this treatment does not increase the kidney efficiency or considerably change the blood retention picture. These patients have sufficient renal tissue to carry them along and the prolonged drainage is used only to facilitate the building up of their other body resources.

I have purposely limited this discussion to the particular points which I wish to make and have refrained from discussing the period of drainage which depends upon the condition of the patient, kidney tests, blood retention tests, cardiovascular studies, vasoligations, and similar subjects about the value of which there can be no question.

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## CANCER TREATMENT RESULTS AS SHOWN IN TWELVE YEAR SURVEY AT EVANSTON HOSPITAL

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THE great majority of cancer surveys have been made by surgeons or roentgenologists, covering their observations of the disease as limited to certain organs or systems of the human body. Very few general reports appear in the literature of the last 10 years.

An attempt is made in the following survey to give all of the available interesting facts, including a follow-up report, concerning the proved cases of cancer that have been admitted to the Evanston Hospital during the last 12 years.

The Evanston Hospital is a 235 bed general hospital and the survey covers the work of 55 physicians representing nearly every department in medicine, these physicians having conducted the treatment in the 453 cases included in the survey. Only cases in which the diagnosis is proved by microscope or by overwhelming exploratory or clinical evidence are included in this report. The untraced cases are not considered in the treated or percentage columns that appear later in the report. One hundred and sixty-eight additional cases were listed in the record room as cancer cases but were excluded from this report because of lack of proved diagnosis, or because of lack of co-operation on the part of 13 physicians in making a follow-up of their 38 cases. The cases of 6 deceased physicians also were not included because permission was not obtained to follow up their patients.

We feel certain of the diagnosis in 453 cases and were able to get a follow-up report as to the physical condition of 93 per cent of these cases as of February 1, 1933. Failure to get a follow-up

report in but 7 per cent of all the cases of the 55 co-operating physicians seems very gratifying. A much greater failure percentage was expected.

The incidence of cancer is about 1 per cent of all admissions to the hospital during the 12 year period covered in this survey. In order to show the points of interest brought out by the study of these 453 cases, a large chart was made depicting all facts ascertained. The chart, however, is too large to be printed. Instead we have made from this chart, and directly from the case records, 10 tables, endeavoring to show the results of our investigation. The chart is kept for reference in the hospital record room.

Reference to Table I will show that the cases are presented under anatomical classification. Data were accumulated as to age, sex, method of diagnosis—that is whether clinical or by microscope—as to length of time between first symptoms and treatment, heredity, the kind of treatment, the present condition of the patient, whether or not there was glandular, regional, or metastatic involvement, how long since treatment, number of inoperable cases, number receiving palliative treatment, the length of time inoperable cases lived, whether the patients died of other disease without the return of cancer, and the number of operative deaths.

The total and percentage columns show that there were 26 per cent male patients and 74 per cent female; that 31, or 7 per cent, of the 453 cases were untraced; that there were 100 inoperable cases that lived an average of but 11 months without treatment from the time first symptoms were noted until death; that 101 received palliative treatment only; that there were 15 operative deaths, or over 4 per cent. This operative death mortality is very high, being near the top in a series of such percentages given as from one to five in other hospitals. Inadequate preoperative preparation of patient and overzealous attempts to treat far advanced cases doubtless explains this high mortality.

Hereditary taint was noted in but 38 cases, or 8.3 per cent. This low percentage, in my opinion, represents lack of knowledge as to the true hereditary history rather than actual facts, and means nothing whatever from a statistical standpoint except to indicate our inability to obtain the real hereditary history in man.

Only 5, or about 4 per cent, of the breast cases showed bilateral breast cancer.

The youngest carcinoma case was that of a girl of 12 with pelvic carcinoma. The oldest carcinoma case was that of a woman of 86 whose life was prolonged several years after simple breast amputation for an ulcerating scirrhus carcinoma. The youngest sarcoma case was in a child of 7 years with sarcoma of the orbit.

The radio knife has been used at this hospital for 3 years only, and then in only 29 carcinoma cases. Those using the radio knife were very favorably impressed with its ease of employment, reduction, and control of hæmorrhage, with the satisfactory scars, and with the possibility of prevention of extension of carcinoma. Enough time has not yet elapsed to note the real benefit of its use.

Table II shows the percentage incidence by systems.

Table III gives the general results of treatment as indicated by the follow-up returns. It shows that radical treatment was attempted in 80 per cent of cases; that of those treated before 1928, 47 per cent lived over 5 years. Of all patients treated before 1928, 33 per cent lived over 5 years; the actual average time being 7 years. The total living since treatment is 49 per cent. Six patients who died of other diseases without recurrence of cancer were not included among those living for any certain period.

Table IV shows the number of breast cases in which patients lived under 2 years, from 2 to 5 years, and over 5 years; indicating that 47 patients before 1928 had radical treatment of whom 60 per cent lived over 5 years; of the 54 patients receiving any treatment 51.8 per cent lived over 5 years.

Table V gives some details as to the result of different treatments in breast cases, consideration having been given as to whether or not there was glandular, regional, or metastatic involvement. It shows that 74 per cent of the patients having no glandular involvement are living while only 46 per cent of the patients with glandular involvement still live and that none of the patients with metastasis are now living.

Table VI gives a record of results of treatment of pelvic cases expressed in number of years living after treatment, also indicating methods of treatment and respective results; showing that 37 per cent of those treated before 1928 lived over 5 years, that 43 per cent of the 42 receiving radical treatment lived over 5 years.

Tables VII, VIII, and IX give the incidence of cancer of cervix, fundus, and adnexa, with treatment and results expressed in 5 year cures, and show that 50 per cent of all patients with cervix and fundus cancers having radical treatment lived over 5 years; that but 1 of the 8 adnexa cancer patients survived 5 years after an attempted radical cure.

TABLE I.—CANCER SURVEY—EVANSTON HOSPITAL 1921–1932

| Region | Organ or system | Sex | | Total number | Untraced | Average age | Diagnosis | | | | | No. of months onset to treatment | Inoperable | Died of other causes without recurrence | Operative deaths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Microscopic | | | | Clinical, only | | | | |
| | | M. | F. | | | | Preoperative | Postoperative | Postmortem | Total microscopic | | | | | |
| Buccal cavity | Lips | 2 | | 2 | | 52 | | 2 | | 2 | | 12 | | | |
| | Tongue | 5 | 1 | 6 | | 59 | 3 | 1 | | 4 | 2 | 18 | 1 | | |
| | Floor of mouth | | | | | | | | | | | | | | |
| | Pharynx | 7 | 8 | 15 | | 52 | 4 | 10 | | 14 | 1 | 12 | | | |
| | Cheek | | | | | | | | | | | | | | |
| 23 | Parotid gland | | | | 2 | | | | | | | | | | |
| Digestive tract | Œsophagus | 1 | 2 | 3 | | 66 | 1 | 1 | | 2 | 1 | 18 | 1 | Suicide 1 yr. later | |
| | Stomach | 9 | 13 | 22 | 1 | 62 | | 10 | 10 | 20 | 2 | 9 | 9 | | 1 Shock |
| | Liver | 2 | 1 | 3 | | | | 1 | 2 | 3 | | 9 | 3 | | |
| | Gall Bladder | 3 | 7 | 10 | | 62 | | 8 | 2 | 10 | | 3 | 6 | | |
| | Pancreas | 1 | 5 | 6 | | | | 3 | 3 | 6 | | 9 | 6 | | |
| | Small intestine | 1 | | 1 | | | | 1 | | 1 | | | | | |
| | Appendix | 1 | 4 | 5 | | | | 5 | | 5 | | 6 | 1 | | 1 Peritonitis |
| | Right colon | 5 | 9 | 14 | 2 | 59 | 3 | 7 | 2 | 12 | 2 | | 4 | | 3 |
| | Left colon | 1 | 2 | 3 | 2 | | | 2 | 1 | 3 | | | 2 | | |
| | Sigmoid | 8 | 15 | 23 | 1 | 57 | 3 | 8 | 5 | 16 | 7 | 9 | 9 | | |
| 54 | Rectum | 5 | 9 | 14 | 1 | 61 | 3 | 2 | 9 | 14 | | 12 | 4 | | |
| Breast | No glandular involvement | | 40 | 40 | | | 2 | 33 | 2 | 37 | 3 | 8 | | | |
| | Glandular or regional involvement | | 58 | 58 | 7 | 53 | 3 | 51 | 1 | 55 | 3 | 10 | | Erysipelas | 1—24 hrs.<br>1—1 hr.<br>1 Pneumonia |
| 122 | Metastasis | | 24 | 24 | | | 2 | 12 | 3 | 17 | 7 | 11 | 13 | Pneumonia 1 yr. later | |
| 6 | Skin | 3 | 3 | 6 | | | 3 | 3 | | 6 | | 18 | | Diabetes 9 yrs. later | |
| Respiratory tract | Larynx | 1 | 1 | 2 | | | | 1 | | 1 | 1 | | 1 | Pneumonia | |
| | Bronchi | 1 | 1 | 2 | | | | 1 | | 1 | 1 | 13 | | | |
| | Lungs | | 2 | 2 | | 51 | | 1 | 1 | 2 | | | | | |
| 8 | Pleura | 2 | | 2 | | | | 1 | 1 | 2 | | | 6 | | |
| Genito-urinary tract | External genitalia | 3 | 2 | 5 | | 48 | 1 | 2 | 2 | 5 | | 9 | | | |
| | Urethra | | 1 | 1 | | | 1 | | | 1 | | ? | | | |
| | Bladder | 16 | 11 | 27 | 6 | 58 | 1 | 22 | 1 | 24 | 3 | 9 | 2 | 1 Coronary | 2 |
| | Prostate gland | 14 | | 14 | | 67 | 6 | 5 | 1 | 12 | 2 | 16 | | | 2 |
| 54 | Kidney | 3 | 4 | 7 | | 62 | | 5 | 2 | 7 | | 10 | 3 | | |
| Pelvic organs | Cervix | | 38 | 38 | 4 | 51 | 24 | 8 | 4 | 36 | 2 | 11 | 3 | Hyperthyroidism 5½ yrs. later<br>Pregnancy | |
| | Fundus | | 31 | 31 | 1 | 59 | 15 | 14 | 1 | 30 | 1 | 10 | 2 | 1 fractured hip<br>1 cerebral hæmorrhage | 1 |
| 100 | Adnexa | | 31 | 31 | 2 | 55 | 7 | 14 | 3 | 24 | 7 | 5 | 10 | | 2 shock |
| | Bones | 10 | 5 | 15 | 1 | 42 | 3 | 6 | 3 | 12 | 3 | 9 | 4 | Coronary | |
| | Muscles | 2 | 1 | 3 | | 48 | 1 | 2 | | 3 | | 4 | 1 | | |
| | Nervous system | 2 | | 2 | | 41 | | 1 | 1 | 2 | | 9 | 2 | | |
| | Unclassified | 11 | 5 | 16 | 1 | | 2 | 7 | 6 | 15 | 1 | 9 | 7 | | |
| | Total | 119 | 334 | 453 | 31 | | 88 | 250 | 66 | 404 | 49 | Average 8 mos. | 100 | 11 | 15 |
| | Percentage | 26 | 74 | 100 | 7 | | 19 | 55 | 14 | 89 | 11 | | 22 | 3 | 4 |

TABLE II.—PERCENTAGE BY SYSTEMS—453 CASES

| System | Total cases | Per cent |
|---|---|---|
| Buccal cavity | 23 | 5 |
| Digestive tract | 50 | 11 |
| Colon, rectum, and sigmoid | 54 | 12 |
| Breast | 122 | 27 |
| Skin | 6 | 1.3 |
| Respiratory tract | 8 | 1.76 |
| Genito-urinary tract | 54 | 12 |
| Pelvic organs | 100 | 22 |
| Skeletal, muscles, nervous system | 20 | 4.4 |
| Unclassified | 16 | 3.5 |
| | 453 | 99.96 |

TABLE III.—RESULTS OF TREATMENT—322 CASES

| | Cases | Per cent | Per cent 5 year cures | Per cent 2–5 year cures | Per cent under 2 years |
|---|---|---|---|---|---|
| Radical treatment—attempt to cure | 260 | 80.8 | .... | .... | .... |
| Palliative treatment only | 62 | 19.2 | .... | .... | .... |
| Group I— | | | | | |
| Treatment over 5 years ago | 172 | 66.1 | .... | .... | .... |
| Living and well | 42 | .... | 24.4 | .... | .... |
| Living with recurrence | 6 | .... | 3.4 | .... | .... |
| Dead, having lived 5 years after treatment | 10 | .... | 5.2 | .... | .... |
| Total living 5 years after treatment | 58 | .... | 33.1 | .... | .... |
| Radical treatment | 123 | .... | .... | .... | .... |
| Total 5 year cures | 58 | .... | 47.1 | .... | .... |
| Group II— | | | | | |
| All cases treated over 2 years ago | 271 | .... | .... | .... | .... |
| Radical treatment | 188 | 69.3 | .... | .... | .... |
| Alive and well 2 to 5 years after treatment | 30 | .... | .... | 15.95 | .... |
| Alive and recurrence 2 to 5 years after treatment | 2 | .... | .... | 1.06 | .... |
| Dead, having lived 2 to 5 years after treatment | 6 | .... | .... | 3.18 | .... |
| Total in 2 to 5 year group | 38 | .... | .... | 20 | .... |
| Total living in Groups I and II 56–38 | 94 | .... | .... | 50 | .... |
| Group III— | | | | | |
| All cases treated in whole series | 322 | .... | .... | .... | .... |
| Received radical treatment | 260 | 80.7 | .... | .... | .... |
| Palliative treatment | 62 | 19.3 | .... | .... | .... |
| Of radical treatment cases— | | | | | |
| Lived 5 years or over | 42 | .... | 16.5 | .... | .... |
| Living—well 2 to 5 years after treatment | 31 | .... | .... | 11.8 | .... |
| Living under 2 years with recurrence | 6 | .... | .... | .... | 2.3 |
| Living 2 to 5 years with recurrence | 7 | .... | .... | 2.7 | .... |
| Living 5 years with recurrence | 6 | .... | 2.3 | .... | .... |
| Living and well under 2 years since treatment | 36 | .... | .... | .... | 13.8 |
| Total living | 128 | 49.2 | .... | .... | .... |
| Dead, having lived 5 years | 10 | .... | 3.8 | .... | .... |
| Dead, having lived 2 to 5 years | 42 | .... | .... | 16 | .... |
| Dead, having lived under 2 years | 80 | .... | .... | .... | 30.8 |
| Total dead | 132 | 50.8 | .... | .... | .... |

TABLE IV.—CARCINOMA OF BREAST—122 CASES

| | Cases | Per cent |
|---|---|---|
| Group I, treated before 1928 | 54 | ..... |
| Alive and well, over 5 years | 15 | 28 |
| Alive with recurrence, 5 years after treatment | 5 | 9.26 |
| Dead, having lived 5 years | 8 | 14.8 |
| Total | 28 | 51.9 |
| Received radical treatment before 1928 | 47 | ..... |
| Total, lived 5 years | 28 | 60 |
| Group II, treated to 1931 | 93 | ..... |
| Alive and well, 2 to 5 years after treatment | 19 | 20.4 |
| Alive with recurrence, 2 to 5 years after treatment | 5 | 5.37 |
| Dead, having lived 2 to 5 years after treatment | 20 | 21.5 |
| Total | 44 | 47.1 |
| Alive and well to 2 years after treatment | 9 | 9.25 |
| Dead, having lived 2 years after treatment | 26 | 28 |
| Total | 35 | 37.63 |
| Total treated including 1932 | 105 | 86 |
| Inoperable | 13 | 10.65 |
| Refused treatment | 4 | 3.28 |
| Total | 122 | ..... |
| Living, of the 105 treated, over 5 years | 20 | 19 |
| Living, of the 105 treated, from 2 to 5 years | 24 | 21.9 |
| Living, of the 105 treated, under 2 years | 9 | 8.57 |
| Total | 53 | 50.47 |
| Dead, as of February, 1932 | 52 | 49.53 |
| Inoperable | 13 | ..... |
| Refused treatment | 4 | ..... |
| Total | 122 | ..... |
| Deaths from other causes—not considered in the 105 treated— | | |
| Erysipelas | 1 | ..... |
| Pneumonia—1 year later | 1 | ..... |

TABLE V.—CARCINOMA BREAST—RESULTS IN 122 CASES

| | Alive 5 yrs. | Alive 2–5 yrs. | Alive 2 yrs. | Dead after 5 yrs. | Dead under 5 yrs. | Total |
|---|---|---|---|---|---|---|
| Without gland involvement— | | | | | | |
| Treated with radium or X-ray only | .. | 1 | .. | .. | 1 | 1 |
| Treated by surgery only | 6 | 10 | .. | 1 | 4 | 21 |
| Treated by combinations | 1 | 6 | 3 | 2 | 5 | 17 |
| Total without gland involvement | | | | | | 39 |
| Total living—28, or 74 per cent | | | | | | |
| With gland or regional involvement— | | | | | | |
| Treated with radium or X-ray | .. | .. | .. | .. | 1 | 1 |
| Treated with surgery only | 4 | 1 | 3 | 2 | 10 | 20 |
| Combinations of X-ray, radium, surgery, diathermy | 6 | 7 | 3 | 2 | 13 | 31 |
| Total with gland involvement | | | | | | 52 |
| Total living—24, or 46 per cent | | | | | | |
| With metastasis— | | | | | | |
| Treated with X-ray or radium | .. | .. | .. | .. | 3 | 3 |
| Treated by surgery only | .. | .. | .. | 1 | 7 | 8 |
| Combinations of X-ray, radium, surgery, diathermy | .. | .. | .. | 3 | .. | 3 |
| Total with metastasis | | | | | | 14 |
| None living | | | | | | |
| Total treated | 105 | | | | | |
| Inoperable | 13 | | | | | |
| No treatment | 4 | | | | | |
| | 122 | | | | | |

Of the 453 cancer cases there were 28 cases of sarcoma included in this survey. Only one of the 28 patients survived 5 years. Had these cases been omitted from the general cancer survey, the percentage of 5 year cures would have been increased somewhat.

Table X shows the type of treatment of sarcoma cases with the results.

On the whole, this survey gives strong evidence that even in a general hospital with 55 independent physicians administering the treatment, their results are very gratifying. Doubtless earlier diagnosis, improved methods as to operative technique, especially as to thoroughness of removal of growths, and the adoption of all reasonable therapeutic means at our command, will lead to greater numbers of 5 year or even permanent cures.

The survey shows that surgery combined with some form of irradiation or diathermy gave better

TABLE VI.—CANCER OF THE PELVIC ORGANS—RESULTS IN 100 CASES

| | Cases | Per cent 5 year cure |
|---|---|---|
| Treated before 1928 | 49 | ..... |
| Alive and well over 5 years | 16 | ..... |
| Alive with recurrence 5 years | 1 | ..... |
| Dead, after 5 years | 1 | ..... |
| Total | 18 | 36.7 |
| Radical treatment before 1928 | 42 | 42.8 |
| Treated before 1931 | 80 | ..... |
| Alive and well 2–5 years | 4 | ..... |
| Alive with recurrence 2–5 years | 13 | ..... |
| Total | 17 | 21.25 |
| Treated to February, 1933 | 83 | ..... |
| Alive and well to 2 years | 15 | ..... |
| Alive with recurrence to 2 years | 3 | ..... |
| Dead, under 2 years | 30 | ..... |
| Total | 48 | ..... |
| Inoperable | 16 | ..... |
| Refused treatment | 1 | ..... |
| Total cases | 100 | ..... |
| Living— | | |
| Sarcoma cases | 6 | ..... |
| Living | 0 | ..... |
| Carcinoma cases | 94 | 55.32 |
| Living | 52 | ..... |

TABLE VII.—CANCER OF CERVIX, CARCINOMA, 40; SARCOMA, 1; TOTAL, 41

| | Cases | Per cent |
|---|---|---|
| Treated before 1928 | 21 | .... |
| Alive and well | 8 | .... |
| Dead, having lived 5 years | 0 | .... |
| Alive—with recurrence—5 years | 1 | .... |
| Total lived 5 years | 9 | 43 |
| Total receiving radical treatment | 18 | 50 |
| Treated before 1931 | 31 | .... |
| Alive and well 2 to 5 years | 2 | .... |
| Dead, 2 to 5 years after treatment | 7 | .... |
| Total lived 2–5 years | 9 | 29 |
| Total treated to February, 1933 | 38 | .... |
| Alive under 2 years | 3 | .... |
| Dead under 2 years | 14 | .... |
| Alive with recurrence under 2 years | 3 | .... |
| Total lived less than 2 years | 20 | 52.6 |
| Inoperable | 3 | 7.3 |

results than either surgery or irradiation alone. Doubtless the recently improved methods of administering irradiation may greatly increase the incidence of cures.

For survey purposes the special cancer charts recommended by the American College of Surgeons are a great aid and I would strongly urge their adoption and especially recommend that they be filled out while the patient is in the hospital, at which time only can all pertinent facts be elicited and recorded.

I would like also to indorse the plan which has been frequently suggested that definite periodic follow-up examinations be made in every case, having the patient report at sufficiently frequent intervals to insure the early detection of local recurrences, proper treatment of which so often avoids further extension and even distant metastasis.

TABLE VIII.—CANCER OF THE FUNDUS—CARCINOMA, 27; SARCOMA, 4; TOTAL, 31

| | Cases | Per cent |
|---|---|---|
| Treated before 1928 | 17 | .... |
| Alive and well over 5 years | 7 | .... |
| Dead, 5 years after treatment | 1 | .... |
| Alive with recurrence after 5 years | 0 | .... |
| Total | 8 | 47 |
| Total receiving radical treatment | 16 | 50 |
| Treated before 1931 | 25 | .... |
| Alive and well 2 to 5 years | 2 | .... |
| Dead, 2 to 5 years after treatment | 2 | .... |
| Total | 4 | 16 |
| Total cases treated | 28 | .... |
| Alive and well to 2 years | 9 | .... |
| Dead under 2 years | 8 | .... |
| Total | 17 | 60.7 |
| Total treated | 29 | .... |
| Total living | 18 | 62 |
| Total dead | 11 | 38 |
| Total carcinoma cases | 27 | .... |
| Living | 18 | 66.6 |
| Inoperable cases | 2 | .... |

4 sarcoma cases—one living 1½ years—1, 5 months, 1, 6 months, 1 dead in 3 months, without recurrence—cause fractured hip.

TABLE IX.—CANCER OF THE ADNEXA—SARCOMA, 1; CARCINOMA, 27; TOTAL, 28

| | Cases | Per cent |
|---|---|---|
| Treated before 1928 | 11 | ..... |
| Alive and well over 5 years | 1 | 9.09 |
| Treated before 1931 | 14 | ..... |
| Alive and well 2 to 5 years | 0 | ..... |
| Dead, after 2 to 5 years | 4 | 28.6 |
| Total treated | 17 | ..... |
| Alive and well under 2 years | 2 | ..... |
| Alive with recurrence under 2 years | 1 | ..... |
| Dead, under 2 years | 8 | ..... |
| Total | 11 | 64.7 |
| Inoperable—not treated | 11 | ..... |
| Only 1 patient lived 5 years | .. | ..... |
| Total living | 4 | 14 |
| Total dead | 24 | 86 |

TABLE X.—SARCOMA CASES

Number of cases, 28.
Number of biopsies, 27.
Youngest, age 7 years.
Oldest, age 76 years.
Average time between onset and treatment, 6 months.
Untraced, 1, after 4½ years.

TYPE OF TREATMENT AND RESULT IN SARCOMA CASES

| | Cases | Per cent of total |
|---|---|---|
| Alive and well 1 to 5 years | 2 | ..... |
| 1 surgery | | |
| 1 surgery, X-ray, and surgery | | |
| Alive and well under 1 year—Surgery | 1 | 3.57 |
| Alive with recurrence 1 to 5 years—X-ray | 1 | 3.57 |
| Dead, having lived 8 years after treatment—Surgery. | 1 | 3.57 |
| Dead, 1 to 5 years | 4 | 14.38 |
| 1 surgery and X-ray | | |
| 1 surgery | | |
| 1 X-ray and radium | | |
| 1 inoperable | | |
| Dead, under 1 year | 18 | 64 |
| 2 surgery | | |
| 4 surgery and X-ray | | |
| 1 diathermy | | |
| 1 X-ray | | |
| 10 inoperable | | |

# AN AUTOMATIC METHOD OF TREATMENT FOR FRACTURES OF THE TIBIA AND THE FIBULA[1]

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IN order to appreciate the need for new methods of fracture treatment we must remember that our criteria of end-results have been altered with the change in the medico-legal aspect of cases. Since the establishment of compensation commissions, juries and insurance companies constitutes a final judge in so many instances, it behooves the surgeon to give this timely topic more serious consideration. Functional restoration, regarded in the past as the ultimate test, is now insufficient. The present public also demands a practically normal reposition of the bony fragments, as demonstrable on the final X-ray films.

In line with modern fracture treatment, which aims toward surety of end-to-end reductions, a simpler and yet more positive method is described for fractures of the leg requiring traction, especially those of the oblique variety. To our knowledge this is the first time that reduction has been mechanically achieved by an apparatus providing exact rotation, traction, and sidewise control, all on the normal anatomical axis, by means of skeletal traction and countertraction. In reviewing the subject of multiple-pin methods we note Putti, Abbott, Pitkin, Boehler, Klapp, and others as advocates; but the majority of these authors manipulate four pins in order to appose the fractured ends or else use the method with devices for bone-lengthening. For many years we have been employing a two-pin method—in association with the regulation fracture table and also with the bilateral expansion bolts attached to the pin-ends, as reported by Dr. Nixon from my service at the King County Hospital.[1] Rotation was found to be unsatisfactory with the ordinary fracture table because of the difficulty of bringing the axes of rotation to coincide. As for the expansion bolts, the variable human element intervenes; and since retention of fragments may be even more difficult than the "setting," reduction is often lost during application of the cast. If we are to be held liable for continued retention throughout treatment, why should we take chances on trial and error methods, known to result in a high percentage of fragment slipping, during or following application of the cast.

To solve the problem of maintaining perfect apposition it was necessary to devise a new apparatus, a small fracture table—only 20 inches long—with mechanism so adjustable that all the aforementioned discrepancies are overcome with an unremitting mechanical force. In a veritable fracture-robot, control has been so perfected over traction, rotation, and abduction or adduction that absolute reduction and immobilization are attained by the surgeon, without skilled assistance. Hence the fracture is not only automatically reduced but the fragments are firmly held while applying the cast. And subsequently, since the pins transfixing the upper and lower fragments are incorporated in the cast, there can be no loss of reduction.

Skeletal traction implies countertraction. The superiority of skeletal traction is now accepted by all surgeons who are acquainted with it, and once employed, skeletal countertraction will draw as many converts. A further advantage to be derived from double wire or pin transfixion is that the proximal fragment, as well as the distal, is under control in readiness for any form of direct bone manipulation. In this method the superior pin supplies the base for the counter pull while traction is made upon the distal pin. Thus the essential attribute of this new mode is skeletal traction plus skeletal countertraction, with a control fulfilling all conditions of adjustability, besides allowing for modification of technique to fit all cases. In the majority of simple fractures and in many of the compound ones, the splint is removed after application of the cast. With the older methods of treatment, when a complicating area of integumentous and soft tissue injury also demands immediate attention, reduction is either postponed or made secondary to the non-osseous therapy. With our method the leg is merely left in the splint without plaster, and, therefore, repair of the fracture, which is fixed in reduction, becomes coincident with that of the soft tissues.

## DESCRIPTION OF THE FRACTURE ROBOT

The splint (Fig. 1) consists chiefly of an oblong aluminum frame, *a*, with two horseshoes, *d*, to hold the pins or wire and a threaded rod, *h*, the means of obtaining traction. These U-shaped attachments, *d*, are provided on their underside with a rack of teeth through which internal or external rotation is readily adjusted by turning the self-locking handle, *b;* moreover, the horse-

[1] Nixon, E. A. Skeletal traction and pressure in treatment of fractures. Am. J. Surg., 1932, xviii, 442.

[1] Demonstrated at the Pan-American Medical Congress, Dallas, Texas, March 21 to 25; 1933.

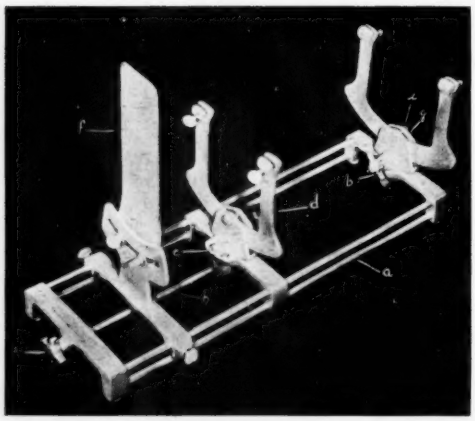



Fig. 1. The automatic splint. *a*, Aluminum frame; *b*, rotation adjustment handle; *c*, sidewise control nut; *d*, duraluminum horseshoes to hold the pin; *e*, traction handle; *f*, removable foot rest.

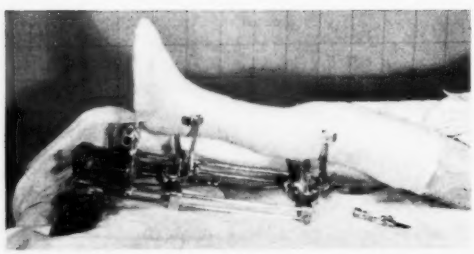
shoes are so proportioned to the rack that the axis of rotation coincides exactly to the axis of the tibia; the horseshoe base, *g*, being centrally pivoted, provides a sidewise swing for correction of medial and lateral angulation, *c*. The adjustable footrest, *f*, is fashioned so that the cast can be applied directly over it; because it is tapered it can easily be removed later.

### TECHNIQUE OF REDUCTION

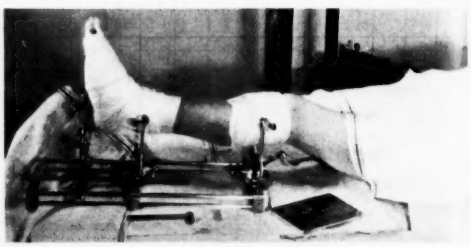
Immediate reduction is preferable; and œdema, either ascending or receding, or vesicle formation need be no cause for postponement. Roentgenograms and hypnotic should precede manipulation, performed under local, spinal, inhalation, or avertin, the local injection of novocain being the method of choice.

The preparation of the leg includes shaving and cleansing with soap and water, and then sterilization with ether and iodine, followed by alcohol should the iodine be very strong. An injection of 5 to 20 cubic centimeters of 2 per cent novocain is made into the skin and down into the periosteum on either side of the tibia at both sites of transfixion, while 20 to 60 cubic centimeters are injected into the hæmatoma and around the end of each fragment. The distal pin is put straight through the center of the tibia at a point two fingers' breadth superior to the tip of the internal malleolus (Fig. 2, A). Recently the site of the superior insertion has been changed to transfix the condyles of the tibia at their widest part midway between the anterior and posterior surfaces; just

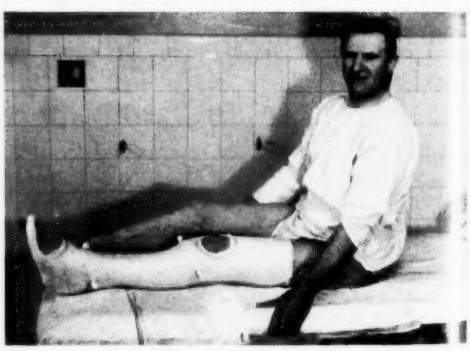
A.



C.



B.



D.

Fig. 2. Steps illustrative of routine reduction. A, First, transfixion of tibia by proximal and distal pins or wire. B, Second, leg placed in splint and fracture reduced, ready for roentgen check. C, Third, encasement of both leg and pins in plaster. D, Fourth, leg lifted free from splint; ends of pins are plaster-covered, and cast is cut out over patella and toes.

stal to the knee joint. Without incising the skin preliminary drilling of the bone each stainless eel Steinmann pin is forced through by rotary nd pressure alone. Sterile dry dressings, about inches square, spiked over each pin-end, afford ample safeguard against infection; they are held close to the wound by a bandage of non-sterile sheet wadding.

The leg is now in readiness for the apparatus. By grasping the foot and pulling on it, the nurse—the only assistant required—raises the leg while the splint is placed beneath, whereupon the pins are clamped to their respective horseshoes. The foot and ankle are then padded with sheet wadding, special attention being given to protection of the heel. All malposition is now controllable; traction and rotation are adjusted, angulation is corrected, and the adjustable footrest is set. When the reduction is judged complete, it is roentgenographically checked. Separation of fragments due to overtraction must be assidiously avoided because, notwithstanding perfect alinement, usually no result can be considered satisfactory without end-to-end pressure contact. Immobilization of satisfactory reduction is completed by the application of a cast, which firmly incorporates the pins and generally extends from midthigh downward over the foot plate to slightly beyond the toes. The sole of the foot should be reinforced with a 4 inch plaster bandage. When the plaster is set, the pin clamps are loosened and the leg in its cast is lifted free from the horseshoes and from the foot plate. Occasionally this process is facilitated by loosening the screws of the foot plate. Ordinary corks are placed on the ends of the pins, which are then covered and fastened to the cast by a plaster bandage. A window cut over the patella serves for subsequent mobilization of the cap; that cut out over the dorsum of the toes allows freedom of movement. The cast is completely cut through to the sheet wadding from top to bottom and later spread open, if necessary.

### OPTIONAL TECHNIQUES

Piano wire permits of the same technique, when used in conjunction with an original wire-tightener, constructed as an integral part of a stainless steel horseshoe (Fig. 3). It is operative in the following manner. The bolt, *n*, is first unloosened in order that *the tightener can be set well up against the horseshoe before clamping the wire;* and when the tension bolt, *n*, is fully screwed in, the wire is sufficiently tight. As soon as reduction is effected the horseshoes, as well as the wires, are incorporated in the cast. We await only the drying of the plaster before releasing each horseshoe from its base by removing bolt, *i*. Hence the leg is removed from the apparatus with the horseshoes molded in the cast, contrary to the preceding technique of incorporating the pins without the horseshoes.

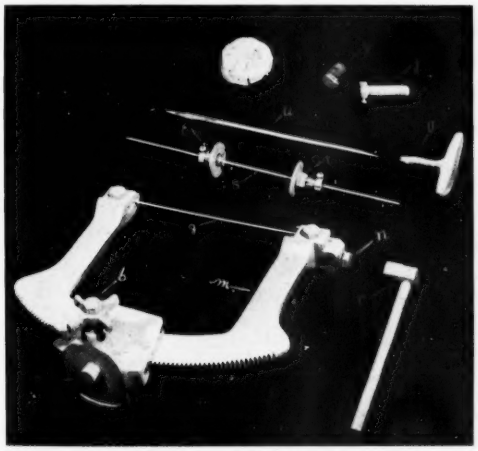


Fig. 3. Accessories for optional techniques. *b*, Rotation adjustment handle; *m*, stainless steel horseshoe for Kirschner wire with our original wire tightener; *n*, wire tension adjustment bolt; *p*, sidewise swivel stud; *q*, piano wire; *r*, wire tightener wrench; *s*, kiddie kar spoke used as wire; *t* and *t'*, two wire "tautners"; the one on the left is contracted, while that on the right is expanded; *u*, ordinary 8 inch Steinmann pin; *v*, pin handle; *w*, felt washer; *y*, ordinary cork; *z*, metal cap to cover pin ends.

For those who prefer wire on theoretical reasons alone, a special technique has been devised whereby the sides of the cast become the instrumental means of keeping the wire tight during convalescence (Fig. 3, *s*). Continued need of the horseshoes and annoyance of extra weight in the cast are thus done away with. For this therapeutic agent, an ordinary kiddie kar spoke or spring steel wire, 65/1000 of an inch in diameter and 9¾ inches in length, is sharpened and tempered at one end. Technique of inserting and clamping this special wire in the horseshoes is the same as for the piano wire. These wires are incorporated in the cast, but the plaster is fashioned with a perpendicular face immediately around each wire to serve as a base for the compression washers. The compression set screw washers are next screwed in and the slots in the washers adjusted so that the set screws can be put on the wires (Fig. 3, *t*). The "wire-tautners," after being pushed tightly against the cast, are fastened to the wire with a screw driver. When the cast is fairly hard, the "tautners" are ex-

A. B.

Fig. 4. Mrs. K. R. A, double fracture of tibia and fibula; B, immediately after reduction.

panded with a wrench up to that point where the washers begin to press into the cast. The wires may now be released from the horseshoes; the ends should be protected with corks and plaster; however, if no further manipulation is anticipated, the wires may be cut off close to the set collars.

*Modification of and accessories* to routine technique are occasionally indicated in obtaining end-to-end reduction. In some cases flexion of the knee may be the essential factor in correcting angulation, accomplished by placing the splint on a box or by setting a sand-bag under the superior end of the frame. In an occasional fracture it may be expedient to elevate the distal end of the apparatus. Persistent anterior angulation can be corrected by a padded compression bandage over the deformity, fastened down to the parallel rods of the frame. Posterior angulation can be overcome by passing a folded towel under the deformity and lifting it up, holding it in position until it is set in the plaster. Altering the tension on the gastrocnemius muscle through adjusting the pressure of the footrest against the sole not infrequently aids in the reduction process.

If the exigencies of the case demand, trans-

Fig. 5. Extensive compound fracture of tibia involving the ankle joint, in which pin transfixed the os calcis. A cast opening made immediately superior to the wound facilitated diagnosis of a possible gas infection, opening later enlarged to treat a traumatic slough.

fixion by pins or wires may be made through the os calcis or through the distal end of the femur; in the event of a double fracture, a third pin may be of assistance.

The cast may either be padded or unpadded, the knee either flexed or extended, but nothing less than a smooth, snug, but non-constricting application will suffice in either instance. It may be occasionally expedient to apply the cast in sections, that is, to incorporate the upper and the lower pin and the immediate vicinity in its respective short cast and to leave the injured area free and exposed for inspection during reduction, for daily therapy, or subsequent operation. These sections may be connected immediately by the third division of the cast and the splint then detached; on the other hand, the two segments may remain separated, with the leg left in the splint for as many days or weeks as required.

### AFTER-CARE

As the majority of cases are reduced immediately under local anæsthesia with surprisingly little attendant shock, if any at all, the patient should be encouraged not only to use the wheel-chair but to walk with crutches. For the latter purpose felt or bath sponge is strapped to the sole or perhaps a rubber overshoe or a split shoe slipped over the foot portion of the cast. For the fastidious or those who wish to resume office duties immediately, a canvas or leather moccasin, soled with felt, may be inexpensively and quickly fitted on. Leg weight bearing is permitted within

a day or two, but body weight is not allowed the first few weeks.

We cannot overemphasize the importance of maintaining pressure contact between the ends of the main fragments even at the expense of some shortening or slight misalinement at the fracture site. In the normal process of repair loss of contact not infrequently occurs from absorption at the ends. To re-establish direct contact the cast may be split, even as early as the end of the first week, from its upper edge down to the fracture level and the plaster cut out directly distal to each end of the superior pin. Then the pin is displaced downward in the cast for a distance of 1 to 3/16 of an inch. The loosened pin, which has not been changed in its position in the bone, is generally re-incorporated at this time, although conditions may indicate leaving the pin free in the small slot in the plaster. To ensure continued contact this pin may be entirely removed as early as the third week. Weight bearing in alliance with this pressure contact assists in provoking early union through the benefits of friction stimulation.

The pins and wire are usually left in for a 3 to 6 week period, and during this interval no attempt should be made to inspect or to dress the wounds. Many years' experience of securely incorporating pins, tongs, or wires in plaster warrants the statement that bone infection does not follow a sterile insertion. Moreover, a pin that is covered and securely incorporated in plaster is usually painless and remains without the patient's knowledge until its removal.

*To remove a pin*, a 4 inch hole is cut on the medial side of the cast and the area cleared to the skin. All plaster is removed from the pin with boiled tap-water; it is further cleansed with a rotary motion of sterile gauze dressings saturated first with ether and the movement repeated with iodine. Iodine saturated gauze is then held closely to the skin around the pin while the pliers withdraw the pin from the opposite side. Dry sterile gauze suffices as subsequent dressings for the pin wounds. If wire has been employed, a similar hole is made in the cast and the wire is cut flush with the skin with sterile pliers. The end is cleansed with ether and iodine, before it is pulled through from the opposite side.

At this time or a few days later, a new well fitting cast—padded or unpadded—is applied, extending to the knee or to the midthigh. The plaster cast is protected by an overshoe as previously described. If desired, an iron walking stirrup can be incorporated, but its transverse portion should be covered with felt or bath-sponge

A. B. C.

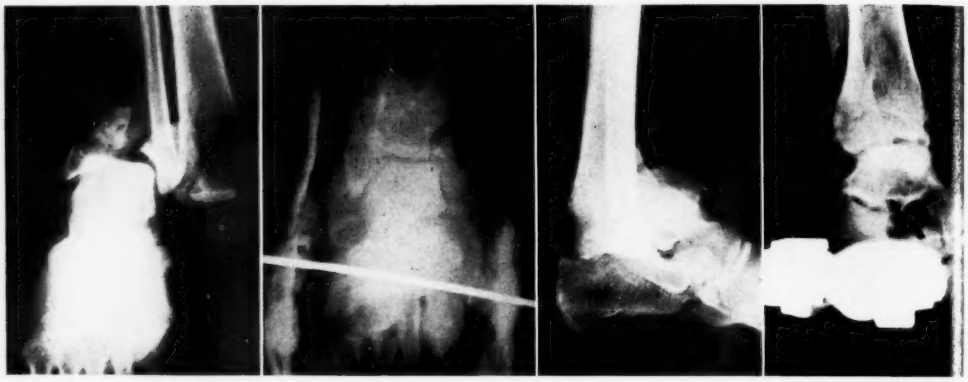
Fig. 6. Mr. J. F. A, Before reduction; B and C, lateral and anteroposterior views afterward.

fastened with adhesive, in order to prevent the patient slipping, and to remove the noise and jar while walking. Body weight bearing is permissible the following day, provided roentgen examination reveals sufficient callus.

The relatively high incidence of delayed and non-union in shaft of tibia fractures, generally noted in monographs on this subject, will be greatly reduced with a system wherein the physiological benefits of immediate ambulation and leg weight bearing are coincident with the maintenance of absolute end-to-end reduction. But in the event of delayed union, perhaps due to arterial or constitutional factors, the cast should be reapplied at 1 or 2 month intervals, body weight bearing being dependent on callus formation. With these measures many cases of open operation can be avoided.

### COMPOUND FRACTURES

For fresh non-extensive compound fractures, traction is obtained in the routine manner. Should the wound encroach, transfixion can be made through the os calcis or the distal end of the femur. The wound can be cleansed by first pouring in ether, followed by iodine, while the skin is centrifugally painted with iodine. Badly traumatized or necrotic tissue should be excised thoroughly but not ruthlessly. Débridement may or not precede reduction, depending on the character of the wound. Closure of the wound is made with mattress sutures of silkworm gut, carefully



A. B. C. D.

Fig. 7. Mrs. E. E. A, Compound fracture with over 2 inches of tibia protruding through skin; B, reduction obtained with pin through os calcis; C, illustrating posterior displacement; D, reduction checked with leg in splint, after which routine cast was applied.

spaced so that the circulation is not strangulated for the skin edges. In the anticipation of much interstitch serous drainage, the wound may be left exposed through a hole in the cast for benefits of open air therapy. These fenestrations serve as diagnostic loop holes for early detection of gas bacillus infection.

In extensive compound fractures or those which do not receive treatment during the first 12 hours after trauma, we advocate Orr's method. After cleansing and débridement, as outlined, the wound is lightly packed with vaseline saturated or Bipp's gauze and then covered with an occluding plaster cast. A window cut superior to but not exposing the wound facilitates the early diagnosis of gas or infection. Should such an infection or an abscess formation occur, the corks are removed from the ends of the pins and the leg replaced in the apparatus. All or part of the cast can then be removed, thus exposing the leg for surgical treatment without endangering reduction

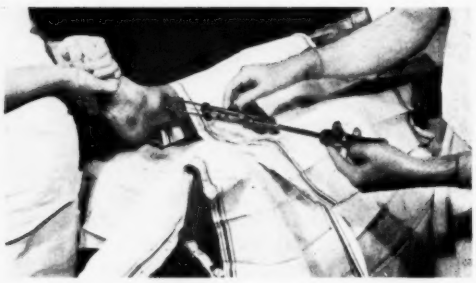


Fig. 8. Illustrating location of transfixion site and manner of inserting the lower wire or spoke, performed under local anæsthesia.

A compound fracture may be so complicated by soft tissue injuries as to preclude the use of a plaster cast. Such a situation is well met by the retention of the leg in the splint. It may be left completely exposed for as many weeks as necessary, while the wound, the skin lesions, and the fracture are receiving simultaneous repair.

If the patient is referred for treatment so late that the compound fracture is already augmented by traumatic osteomyelitis, draining sinuses, or abscesses, treatment can be followed as above described. Moreover, if Baer's method is preferred, the leg may be retained in the splint, with full exposure, or a window may be made in the cast for supervision of the maggot farming.

For those who prefer to treat compound fractures by chemical irrigation methods, the insertion of the pins or wire and the placement of the leg in the splint are made in routine manner. After cleansing and débridement the tubes are inserted. The leg can be left in the splint during convalescence, but to ensure the leg from sliding on the wire, thick felt "buttons" (Fig. 3, *w*) or large corks slipped over the wire, should occupy that space between the leg and the side of the horseshoe. If the wound is central, each pin or wire may be encased individually in its own short plaster segment, leaving the central portion of the shaft open for treatment. All cases of compound fractures are given a prophylactic combined injection of antitetanus and gas bacillus serum.

SOFT TISSUE INJURIES OR COMPLICATIONS

For fractures associated with burns, loss of skin, large ulcers, severe soft tissue injury with gangrenous sloughing, or late soft tissue complications, the technique for chemical irrigation is adhered to. With the patient movable and the whole leg exposed, local treatment or plastic surgery can be carried on without interference or postponement of reduction and union.

MALUNION AND NON-UNION

This method is admirably adapted to malunion and non-union, for the splint is small and readily sterilized in the autoclave. For open operation, the entire leg besides several inches above the knee is surgically prepared and draped, preliminary to inserting the pins (Fig. 9, A). The pin-ends must be covered with ordinary corks or with metal caps (Fig. 3, *y*, *z*) to prevent an accidental perforation of sterile sheets or operator's gloves. The gloves are then changed and with the continuation of sterile technique the necessary incision is made to free the malunion and to freshen the bone-ends, after which the leg is placed in the splint and clamped in position (Fig. 9, B). In simple malunion the fracture is visibly reduced, and only soft tissue sutured, preparatory to encasing the leg and pins in the routine cast.

For the more difficult non-unions, the technique is the same as for malunion, with the exception that the sliding bone-graft is prepared and slipped into position, where it is positively held by the automatic splint. After closure of the skin, application of the cast is immediately made with assurance of no loss in reduction or displacement of graft (Fig. 2, C). This saves that embarrassing moment of finding that the graft shifted while applying the plaster, a rather common disclosure with the older methods.

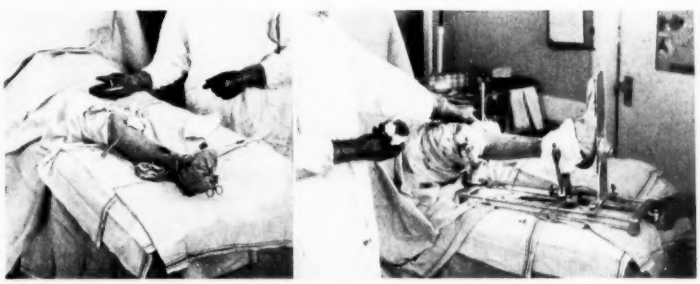
ADVANTAGES

Of the many advantages of this new method, its chief merits are the ease of obtaining and the positiveness of holding reduction, both at time of application of cast and during convalescence.

Double pin or wire transfixion provides all the benefits of skeletal traction plus those of skeletal countertraction. Both the upper and the lower fragments are individually under direct control during apposition of the fractured ends. Furthermore, by literally nailing the bones to the cast, we gain definite insurance against any later displacement. It is this anchoring of reduction that permits immediate ambulation with its many physiological and economical benefits. For instance, movement on crutches increases muscle tone and improves the circulation, locally and generally, with increase of appetite and betterment of digestion. Since long continued hospitalization under traction and that annoying daily adjustment are dispensed with, this method proves a boon to all.

The chief requisite in obtaining reduction of leg fractures is traction, amply supplied by the splint. This advantage is not without an attendant danger, as so much traction at one's command must be controlled. Too much traction must be avoided, as non-union can be frequently attributed to this factor. Direct pressure contact before leg is placed in cast is imperative to reduction, even at the sacrifice of slight overriding.

This automatic splint, acting as a fracture robot, obviates the necessity of skilled assistants. Too much reliance on human assistance, with the fatigue element intervening, is creative of uncertainty and anxiety as to maintenance of reduction. But the surgeon acquires full confidence on initial usage of this mechanical assistant, because variation in tension is incompatible with the vise-like arrangement that holds the reduced fragments.



A. B.

Fig. 9. Technique for malunion or non-union is similar to routine reduction, except that the whole splint is sterilized and that reduction is carried out under the eye, as demonstrated by A and B.

A. B.

Fig. 10. Mrs. K. R., a case received in malunion. A, Before operation; B, result obtained by osteotomy and utilization of the splint sterilized.

Selection of procedure from a triad of special techniques will fit any case in which immediate or late complications limit the use of plaster of Paris. When an extensive soft tissue injury demands daily therapeusis, the leg may be left in the splint, entirely exposed for as many days or weeks as necessary. The advantages are evident, in that there is simultaneous repair of both bone and tissue under the most advantageous conditions. These patients can be easily moved by wheelchair, out of doors, to surgery, or to X-ray room. To meet other conditions the cast may be applied by incorporating the upper pin in a short section, and likewise incorporating the distal pin in another section, leaving the central intervening space entirely free of plaster. This precludes any side-to-side bone movement upon the pin or wire in the horseshoes, and also any motion at the knee or ankle. On healing of the lesion, this exposed section is covered by a cast which is connected with the upper and lower segments, whereupon the splint is detached, with the added advantage of crutch ambulation. Another technique illustrates the adaptability of the method to change during the course of treatment, for the plaster encased leg may require attention, when some sequelæ develops, such as an abscess formation. The leg is therefore replaced in the splint, then all or any portion of the cast is removed. This is attained without endangering reduction.

Ease of obtaining end-to-end reduction is attributable, to a large extent, to the precision of rotation construction. It provides for individual rotation of the fragments on their exact anatomical axes. Horseshoes of different widths are used with the assurance of still having the axes of rotation coincide. An oblique transfixion through the tibia, due perhaps to hasty technique or through necessity of encroaching wounds, in no way prevents a normal axial rotation. Moreover, the special foot-plate is adjustable to correspond with the rotation of the foot.

Fluoroscopic or roentgen examination is not interfered with by intervening shadows or obstructing metal parts, either at the time of reduction, or later, should the fracture tablette be retained. Since reduction can be checked and then perfected before immobilization in the cast, this method eliminates the expense and worry of wedging or recasting. The fact that the patient is ambulatory by crutch or wheelchair solves the problem of using the X-ray in the small hospital with no portable machine. When it is obligatory to retain the leg in the splint, that is, without plaster coverage, the patient can still be moved. Because of its size the apparatus is readily portable; like an automaton, it has no attachment with bed, ropes, or weights.

With perfect alinement, which warrants early leg weight bearing, it is obvious that this new therapeutic agent shortens the period of disability, of great concern to the modern surgeon. Since most of these patients are crutch ambulatory and visit the doctor for inspection and X-ray checkup, hospitalization is reduced to the minimum.

The fact that the machine is small enough to be easily sterilized, in itself inaugurates a new method of treating malunion, non-union, and the unusual compound fracture. For any type of compound fracture this method lends itself admirably and as well to any current procedure.

The fundamental principle of the method—skeletal traction and skeletal countertraction as employed with the mechanical tablette—remains the same regardless of mode of procedure. Furthermore, the flexibility of the method permits a wide selection of transfixion means: the Steinmann pin, Kirschner wire, or spoke with "tautners"; immobilization maintained with or without plaster-of-paris fixation; the cast, padded or unpadded; the knee in flexion or extension; and choice of anæsthesia to suit the case. With only a few minor changes, the method has been successfully adapted to fractures of both bones of forearm.

SUMMARY

An original method of treating fractures of the tibia and fibula has been described, whereby fragments are automatically alined and immobilized.

# SURGICAL ASPECTS OF POLYCYSTIC KIDNEY

## Report of Eighty-Five Surgical Cases[1]

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REFERENCES to standard textbooks and other literature would indicate that there is uncertainty regarding the advisability of surgical treatment for polycystic kidney and that there are but few data available in regard to the results of treatment. This, we believe, is largely the result of too few cases having been studied to allow of definite conclusions being drawn. In one of the recent textbooks, reference is made to the report of Brin, in 1905, as follows: "Nephrectomy was carried out in 17 cases—the mortality has been so high that this procedure stands condemned."

Our experience would seem to lead to a contrary opinion. A review of our records shows that some type of surgical procedure was performed at The Mayo Clinic on 85 patients who were found to have polycystic kidneys. Nephrectomy was performed in 31 cases. The Rovsing operation (puncture of cysts), or excision and drainage of the cysts, was carried out in 29 cases, and exploration, either with or without an associated operation on some other abdominal viscus, was performed in 25 cases.

### INDICATIONS FOR SURGICAL INTERFERENCE

Since most of the symptoms accompanying polycystic kidney are secondary to renal insufficiency or vascular disease, the majority of patients will present themselves to the internist rather than to the surgeon. However, with the onset of pain, hæmaturia, tumor, or secondary renal infection, the surgeon is usually consulted for relief.

The indications for surgical interference may be either primary or secondary. The primary factors are pain from distention of cysts and persistence of hæmaturia. Among the secondary complications are localized or diffuse renal infection, with pyonephrosis, renal abscess, lithiasis, tuberculosis, and neoplasm. Surgical measures may be required for evacuation of cysts, in order to relieve intrarenal pressure and prevent further injury to the remaining renal tissue, as suggested by Rovsing.

In determining the advisability of operation from the standpoint of combined renal function, the peculiar conditions at hand present unusual problems. In the first place, as one of us has previously noted, lack of parallelism between the excretory and retention tests of renal function is often observed with polycystic kidneys. In other words, there is often marked delay and reduction in excretion of such dyes as indigocarmine and phenolsulphonephthalein, while the values for blood urea and creatinine may be normal or but slightly elevated. This may be explained in part by intrarenal anatomic conditions causing delayed excretion. The retention test, therefore, usually will be the more accurate index of renal function. If the value for urea is more than 50 to 60 milligrams for each 100 cubic centimeters of blood, the advisability of operation is open to question, except as an emergency measure, or when some temporary functional deterrent may be present, such as lithiasis or acute unilateral renal infection. In the light of our present experience, intravenous or excretory urography is a comparatively accurate index of renal function. Recognizable deformity will be visualized in fully two-thirds of the cases when the renal function will permit visualization. The details of the pelvic outline may be insufficient for interpretation, however, and the condition may not be recognized unless retrograde urography is employed. As a means of determining the comparative function of the two kidneys, intravenous urography will be of great practical value also. Adequate visualization of the pelvis of but one kidney can be regarded as sufficient evidence of normal renal function to warrant removal of the other kidney. In the interpretation of the intravenous urogram one should remember, however, that visualization of the renal pelvis may be absent or exceedingly dim with: (1) idiosyncrasy on the part of the patient in excretion of iodine, (2) combined renal insufficiency as indicated by a value for urea of 60 milligrams or more in each 100 cubic centimeters of blood, and (3) some temporary reflex inhibition of renal excretion.

[1]Read before the American Association of Genito-Urinary Surgeons, Washington, May 8 to 10, 1933.

*Pain.* In most of our series of 85 cases in which surgical procedures were carried out, a complaint of pain was made. It was usually referred to as a dull ache localized largely in the lumbar region. In the presence of huge kidneys, pain may be caused by tension on the renal pedicle. Pain may also be caused by increase of intracystic pressure, particularly when the cysts are of extremely large size. In several cases one or two large cysts were present and their evacuation was followed by relief of pain. Intracystic hæmorrhage, with resulting overdistention, may occur and may be the cause of renal pain. Pain may also occur as the result of ureteral obstruction by blood clots.

*Hæmorrhage.* In a recent review of clinical data concerning 193 patients with polycystic kidney observed at the clinic, it was found that gross hæmaturia occurred in 30 per cent. The combination of hæmaturia with a tumor felt in a lateral upper abdominal quadrant is usually so suggestive of neoplasm that surgical exploration and even nephrectomy have frequently been reported before the true condition was recognized. In most cases the hæmaturia is moderate and continues only a few days. Intracystic hæmorrhage probably occurs often with polycystic kidney, without hæmaturia. On cross section of the kidney, cysts are often found, containing dark colored material, which very evidently represents the residue of a previous hæmorrhage. If intracystic hæmorrhage is very slight or intermittent, neither pain nor hæmaturia may occur. However, if the hæmorrhage is continuous, the cysts either become distended and cause severe pain, or they may rupture into the renal pelvis with resulting hæmaturia. If the hæmaturia is excessive or long continued, surgical interference may be indicated. Evacuation and drainage of these cysts, particularly when large, may suffice. Should there be evidence of secondary widespread renal destruction, nephrectomy may be necessary. Incidentally, it should be remembered that hæmaturia with polycystic kidneys does not necessarily signify its renal origin. Coincident bleeding from other parts of the urinary tract often has been observed, and their exclusion from consideration, by means of cystoscopy, usually is necessary.

*Renal infection.* Urinalysis will disclose the presence of a small amount of pus in the majority of cases of polycystic kidney. Many patients will complain occasionally of intermittent frequency of micturition or of dysuria. As the cysts become distended and project into the lumen of the calices they can readily cause inadequate drainage of the urine with secondary infection. It is surprising that infection which requires surgical treatment does not occur more frequently in these kidneys. Such infection is usually found in one kidney only, suggesting its anatomical origin. Widespread renal infection may have a most insidious onset and may not give rise to acute symptoms until the renal tissue is largely destroyed. Infection of intracystic origin, confined to one or more adjacent cysts, is often observed. Perinephritic abscess, having its origin in infected cysts, may occur. Stone is occasionally found with polycystic kidney, and probably occurs secondary to insufficient drainage of a calyx. Calculi were found in 5 of the 85 cases and were accompanied by so much infection that nephrectomy was necessary. Chemical examination revealed that they were composed largely of calcium phosphate and were probably found as a result of inadequate renal drainage.

### INCISION, EXCISION, AND ENUCLEATION OF THE CYSTS

Incision, excision, and enucleation of cysts are used to accomplish relief of pain caused either by pressure of the polycystic mass on adjacent structures or by intracystic distention. When the cysts are of moderate size, multiple puncture, as suggested by Rovsing, is the preferable procedure. This may be combined with excision or enucleation of larger cysts which may be accessible to such procedures. With infection present within the cysts, unless complete drainage of the perirenal region is established the infection may extend into the remaining renal as well as perirenal tissues, and nephrectomy will be required. For this reason, operations of this type should not be undertaken unless one is certain that the function of the opposite kidney is capable of sustaining life. The results of incision, excision, and enucleation of cysts of polycystic kidney are variable. Rovsing reported several cases in which remarkable amelioration of pain occurred subsequent to multiple puncture; in addition, the renal function was considerably improved. Other surgeons have confirmed these results in some cases, whereas others have reported failures, and have found that secondary nephrectomy became necessary later. Brin reviewed 16 cases treated by incision of cysts, and stated that there was a mortality rate of 25 per cent in this series, and that results among patients who lived were uncertain.

In our series there were 24 cases in which the Rovsing operation, or puncture of multiple cysts, was performed, and 5 additional cases in which cysts were removed or enucleated. There were 4 deaths in hospital from uræmia, perirenal and retroperitoneal bleeding, and infection; this gives

TABLE I.—ROVSING OPERATION AND REMOVAL OF CYSTS

| | Patients | Deaths in hospital |
|---|---|---|
| Rovsing operation | 24 | 4 (16.6 per cent) |
| Removal or enucleation of cysts | 5 | |
| Total | 29 | 4 (13.8 per cent) |

Survived operation (25 cases)

| | |
|---|---|
| Patients now living | 13 |
| Less than 3 years | 2 |
| 8 to 21 years | 11 |
| Patients now dead | 7 |
| Lived more than 10 years | 1 |
| Lived 5 to 10 years | 3 |
| Lived 3 to 5 years | 2 |
| Lived less than 3 years | 1 |
| Not traced | 5 |

a mortality of 13.8 per cent. Thirteen of these patients are living and in fairly good health at the present time, after periods varying from 3 to 21 years following operation. Subsequent deaths occurred in 7 cases, in periods varying from 1 to 17 years (Table I).

NEPHRECTOMY

Nephrectomy was indicated and performed in 31 cases. There was but 1 death as the result of this operation; the patient was a man, 67 years of age, whose removed kidney also contained an adenocarcinoma graded 3. The youngest patient was aged 21 months, and the oldest, 69 years. Nephrectomy was performed for the most part because of advanced renal infection associated with marked reduction or destruction of renal function. Included in this group were 5 patients with calculi and 3 with malignant disease. In 3 of the cases, nephrectomy was performed as a secondary procedure subsequent to puncture of cysts (Rovsing operation). Eighteen patients of this group are living at the present time, from 1 to 19 years after operation. Particular attention is directed to a patient, 43 years of age at the time of nephrectomy, who has reported his condition as being excellent 19 years after nephrectomy. The patient who was 21 months of age at the time of nephrectomy has been in good health during a period of 14 years and 4 months (Table II).

Practically all of these patients who have lived more than a year have reported their condition to be good or excellent, with the following exceptions After a period of 9 years, one patient reported some pain in the opposite renal region; another, after 7 years, reported enlargement of the remaining kidney and hæmaturia; another reported hæmaturia and dysuria 1 year and 7 months subsequent to nephrectomy. Three patients who

TABLE II.—RESULTS FOLLOWING PRIMARY NEPHRECTOMY FOR POLYCYSTIC KIDNEY (28 CASES)

| | Patients | Per cent |
|---|---|---|
| Now living | 18 | 64.2 |
| After 19 years | 1 | |
| 13 to 19 years | 4 | |
| 7 to 13 years | 3 | |
| 4 to 17 years | 3 | |
| 8 months to 4 years | 7 | |
| Dead | 5 | 17.85 |
| Lived 9 to 13 years | 2 | |
| Died within 3 years | 2 | |
| Died in hospital | 1 | |
| Not traced | 5 | 17.85 |
| Nephrectomy was performed secondary to Rovsing operation in 3 additional cases. | | |
| Total number of nephrectomies | 31 | |
| 1 patient died in hospital, mortality | 3.2 per cent | |

were subjected to nephrectomy secondary to the Rovsing operation, died subsequently; 1 after 8 years, 1 after 6 years and 5 months, and 1 after 2 months. In all 3 cases death was due to uræmia.

SURGICAL EXPLORATION

Explorations of polycystic kidneys, without other surgical procedures on them, were carried out in 25 cases. In 11 of these cases intra-abdominal operative procedures were carried out for lesions of one or another of the intra-abdominal viscera, and the presence of polycystic kidneys was an accidental finding. The discovery of polycystic kidneys in the course of abdominal operations in so large a number of cases is suggestive of clinical negligence. However, many of these patients were operated on before methods of diagnosis were as accurate as they are at present. Furthermore, it is surprising how often bilateral renal enlargement is not detected in abdominal palpation. Owing to the great difference in degree of involvement which often occurs, frequently only one kidney is found enlarged on palpation. This may account for the erroneous clinical diagnosis of renal neoplasm which is often made, and with possible disastrous results, if nephrectomy follows. With the aid of modern methods of diagnosis and particularly with the more general employment of intravenous urography, attention should usually be called to the condition present, even if other clinical data fail.

Coincident cysts in the pancreas, liver, and other organs, which might confuse the clinical picture, are often found in the course of abdominal exploration. These cysts are usually confined to a limited region, usually are not progressive in size or number, and do not seem to affect the function of the organs involved. They may occasionally

TABLE III.—EXPLORATIONS FOR POLYCYSTIC KIDNEYS

| | Number | Polycystic kidneys* |
|---|---|---|
| Patients | 14 | 11 |
| Died in hospital | 1 | 0 |
| Mortality per cent | 7.1 | |
| Now living | 6 | 5 |
| Now dead | 6 | 6 |
| Not traced | 1 | |

*Accidentally found at time of other intra-abdominal operations.

become very large, in one case in which we performed exploration, a cyst of the liver was found to be of such size as to cause caudad displacement of the kidney to the level of the crest of the ilium. Occasionally large cysts are found in the liver and in other organs, without renal involvement.

Major surgical procedures were carried out in this group of cases, for cholelithiasis, uterine fibromata, duodenal ulcer, and appendicitis, and in one case colostomy was performed for carcinoma of the rectum. None of the patients died subsequently, over periods of from 1 to 10 years. Five patients of the group are living, for periods varying from 6 to 10 years; 2 of them are in good condition (Table III).

It would seem, therefore, that intra-abdominal surgical operations can be carried out in the presence of polycystic kidney without appreciable increased risk, provided combined renal function is within normal limits.

## SUMMARY AND CONCLUSIONS

The contention that surgical treatment of polycystic kidney is seldom, if ever, indicated is erroneous. Complications with polycystic kidney, which require surgical treatment, occur frequently. The estimation of renal function is of fundamental importance in determining the prognosis and the advisability of operation. Because of the anatomical conditions present in the polycystic kidney, retention tests of renal function usually give a better index than excretory tests.

Evidence of marked disturbance of function of both kidneys such as is indicated by a value for urea of 50 to 60 milligrams or more for each 100 cubic centimeters of blood, usually will contraindicate surgical treatment except as an emergency measure. When complications exist in one kidney which would indicate nephrectomy, it is essential first to determine whether the degree of function of the other kidney is sufficient to sustain life. Bilateral renal deformity visualized by intravenous or excretory urography, should serve in many cases to call attention to the possibility of polycystic disease. It should also serve to make evident the comparative degree of function in either kidney and so govern the type and the advisability of operation. A polycystic kidney, where a clinical diagnosis of renal tumor had been made, has been removed not infrequently. The most common complication requiring surgical treatment, occurring with polycystic kidney, is diffuse or localized infection. Diffuse, subacute renal infection may have an insidious onset, and there may be but few localizing symptoms. Renal pain is a common symptom and is usually described as a dull ache, although it may become acute. It may be caused either by excessive renal weight exerting a pull on the renal pedicle, by intracystic or external pressure, or by infection. Puncture or enucleation of one or more large cysts may serve to ameliorate or eradicate pain. Hæmaturia, usually of moderate degree and limited duration, may become copious and long continued. Such hæmaturia is usually the result of intracystic hæmorrhage with rupture of the cyst into the renal pelvis. Excision or enucleation of such cysts usually will suffice to control the hæmorrhage. Should destruction of the kidney be extensive, or accompanied by secondary infection, nephrectomy may be necessary. Other complications observed with polycystic kidney are renal calculus, neoplasm, tuberculosis, and hydronephrosis. The value of the Rovsing operation, which was conceived for the purpose of removing pressure by the cysts on the remaining renal parenchyma, still remains undetermined. Theoretically it has much in its favor. Unfortunately, secondary infection or a persistent urinary fistula may develop following the operation, necessitating nephrectomy. If such complications could be obviated, the procedure might well merit further consideration. It is difficult to evaluate the results obtained in the few cases in which the Rovsing operation was successfully carried out. Although many patients lived for a long time after operation, this is equally true in cases in which surgical treatment was not employed.

# A TWO STAGE OPERATION FOR FISTULA-IN-ANO

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AN important feature in the surgical management of fistula-in-ano is the prevention of deformity of the anal sphincters with consequent impairment of their function. That some degree of incontinence following operation for fistula was a frequent complication in the past is evident by the fact that one frequently heard the opinion that some impairment of sphincteric function was to be expected. Today interference with anal continence should not follow operation for fistula. It is our belief that this can best be achieved by a two stage operation, and this report presents our experience with this type of procedure in 266 cases of anal and rectal fistula.

All descriptions of the operative technique for fistula emphasize the necessity for a careful localization of the internal opening in the internal and complete varieties and for the determination of the various ramifications of the fistulous tracts. The latter are then completely excised or incision and proper drainage will be sufficient when tracts extend deep into the pelvis, laterally into the buttocks, or anteriorly into the groin.

To eradicate the infection completely and to remove the source by which the fistulous process has been maintained, the overlying tissues must be completely severed. This will include the external sphincter where the internal opening is found near the anal margin in a fissure or anal crypt, and also the internal sphincter where the internal opening is in or above it. It is generally held that the external sphincter may be cut through with little fear of disturbance in function so long as the muscle is severed at right angles to the direction of its fibers. Whenever the external sphincter is severed, due regard must be given to the disturbances that may follow if satisfactory union of its ends does not take place. Proper function of this muscle is essential in maintaining the closing tonus of the anus. The internal sphincter is far from adequate in performing this function. Matti estimated the importance of the external sphincter as maintaining 60 to 65 per cent of the total closing tonus, since, when its influence is removed, the internal sphincter acts peristaltically and maintains only a transitory resistance to a dilating force. He found that the internal sphincter assists in closing the anus by mechanical, not reflex, stimulation of its intramuscular plexus by the persistent tonus of the external sphincter.

Various methods have been advocated and are in use for dealing with the anal muscles. With a grooved director passed through the fistulous tract and internal opening, the overlying tissues and the sphincter are incised (1). Or the fibrous tract may be excised and the muscle severed at the point where the internal opening is found (3, 5, 7). In both types of operation, nothing further is done to the severed muscle except to avoid too firm or prolonged packing. The muscle ends rarely heal by direct union; a small amount of retraction of the ends always follows severance of the muscle and, as a result, a variable amount of scar tissue fills in the space. Depending upon the firmness of this scar tissue or its amount in relation to the anal canal and muscle, sphincter function will be normal or impaired. After excision of the tract, Martin removes all overhanging tissues, even if a portion of the sphincter arc is sacrificed. He finds that this flattened scar will present an even surface for the remaining portion of the sphincter to contract against, giving a surprising degree of control. Buie emphasizes the importance of properly packing the wound and states that a solid block of scar tissue will form throughout the extent of the wound. The anal sphincters will then grow to the scar tissue and close the anal canal efficiently.

Less frequently, radically different procedures have been mentioned. The cut ends of the sphincter may be sutured to the deeper muscles, the internal sphincter or levator ani (11). If the muscle must be cut through laterally, Longacre suggests that the sphincter be reconstructed by three or four mattress sutures.

These procedures prove satisfactory in the majority of cases. Occasionally, however, in spite of careful postoperative care, the resultant scar is irregular and distorted, and cannot act as a suitable fixed point against which the sphincter may pull. Some degree of incontinence, therefore, follows. Perhaps these untoward results may be due to variation in the structure of the external sphincter. As Hiller pointed out so well, the external sphincter consists neither entirely of fibers encircling the anus, nor of fibers extending anteroposteriorly, but is a mixture of the latter type with fibers encircling the anus either anteriorly or posteriorly, in varying proportions. His work showed, further, that the springing

apart of the cut muscle ends, the factor affecting continence, is, in part, prevented by the fixation of the sphincter muscles to the skin and mucous membrane by the fibro-elastic terminations of the longitudinal bowel coat, as well as by the fibers of the external sphincter which encircle the anus posteriorly and end in the levator ani muscles. On this basis he explains the advantage of cutting the sphincter at a second stage when it has become firmly fixed to surrounding structures by fibrous tissue.

Buie suggests a multiple stage operation in very extensive and complicated fistula, where widespread dissection and much loss of tissue is necessary. In such cases, the external sphincter is not severed until the wounds external to it have practically filled in. However, a two or more stage operation has not been generally advocated. In 1907, Pennington described his so called "seton method" for operation on fistula to preserve the contour of the anus as well as its muscular function. Briefly, the method was as follows: Over a grooved director in the fistulous tract, an incision was made from its distal end to a point close to the anal wall. The knife was then turned and an incision made on the proximal side of the tract, "salmon's back-cut." A seton was next passed through the opening entering the bowel and tied loosely around the tissue remaining and undivided. The seton consisted of a narrow strip of gauze which was replaced in 72 hours, when the wound was redressed, by another of one or two strands of heavy silk or linen. Later, when the wound had filled in and healing had extended down to the thread, the tissues, previously undivided, which included the sphincter, were then cut through and through. By operating thus, Pennington found that no deep sulcus was left to mutilate the anus, as frequently followed the usual plan of dividing the muscle. The internal opening in its relation to the tract could be altered so that the muscle would never need to be cut at an oblique angle to its fibers. The theoretical objection that there would be constant reinfection from the setonized tract, which would prevent healing, was never proved by his practical experience. It is a modification of this "seton method" which we have used and will describe.

The two stage operation, employing the seton, has not been used routinely in every case of fistula. A considerable proportion of fistulæ are very superficial in the perianal tissues, and excision of the tract requires little removal of tissue. A small number exist as a direct tract in the midline, both internal and external openings, opposite each other. For these types, excision of the fistulous tract with immediate incision of the muscle down to the internal opening will be adequate. Almost half of the cases of fistula, however, are much more extensive and in these a two stage operation is found necessary.

Of 266 patients, this operation was performed in 119. The severity of the fistulous process varied widely. Twenty-four were of the "horseshoe type," bilateral tracts communicating either anterior or posterior to the anal canal. One patient presented 14 external openings. Sixty-two had two or more external openings. Eight gave both clinical and histological evidence of tuberculous infection. In one patient with a positive blood Wassermann, histological examination of the tissue strongly suggested a syphilitic process. In another, the fistulous tract communicated with a postanal dermoid cyst.

### OPERATIVE TECHNIQUE

The importance of definitely locating the internal opening has been pointed out previously. The injection of a solution of methylene blue (two parts) and hydrogen peroxide (one part) will identify the branches of the tract and, usually, the internal opening. Occasionally, this has temporarily healed over and the dye does not appear in the lumen of the anus or rectum. As the tract is dissected out of its bed, the point at which it communicates with the bowel can then be detected. Since the internal opening is most frequently in the base of an infected or torn crypt, or fissure, it is advisable to explore those crypts in the portion of the anal canal which adjoins the proximal portion of the tracts. As Buie suggests, it occasionally is necessary in this approach to cut down on the crypt in order to locate the internal opening beneath it.

A grooved director is inserted into the tract through its external opening and passed as far as it can go with ease. The tissues overlying the director are incised. The director can then be made to pass further along a tortuous tract until the bowel wall is reached. The base of the fistulous tract is completely dissected out, but only as far as the bowel wall. A bed of healthy tissue is thus left to facilitate prompt healing. In like manner, all the tracts are dissected away and, as a rule, they will all communicate with each other, usually at a point a short distance before the main branch enters the bowel. Two or more internal openings are uncommon, but, when they do occur, are treated in the same manner. A flexible probe is passed from within the anus through the internal opening into the wound and bent so as to remain in place. The proximal portion of the main tract remains, at this stage, dissected free from its bed

but still attached to the bowel wall. This is now severed from the bowel wall as close to the muscular coat as possible. The probe which has been kept in place through the internal opening is now threaded with a double strand of heavy silk and the latter drawn through the opening and out in the wound. It may be found that the direction of the tract and its internal opening has been at such an angle to the fibers of the muscle that when the muscle is cut through, the incision will not be at right angles to the fibers. If this occurs, the tissues lateral to the opening are incised to one side or the other to permit of cutting the muscles in the desired direction. The silk thread is now ready to be tied. It will be noted that the only tissues within the grasp of the ligature are the sphincter and its covering of skin and mucosa. Before tying, the thin strip of skin and mucosa that would be in contact with the thread is pulled up and cut away, thus exposing the muscle fibers. The silk is then tied against the muscle snugly but so as not to cause constriction. It now surrounds only the muscle, which has been left undisturbed (Fig. 1).

Cutting of the muscle is reserved for a second stage. About 1½ inches of the ends of the thread are retained to permit of its ready identification. The wound is now packed in the usual manner. This packing is removed in 72 hours. Occasionally, only a portion is removed at this time, and the remainder on the fourth or fifth day. The wound is then dressed daily or every other day. In the after treatment which is most important, care is exercised to avoid bridging of the sides of the wound and the formation of pockets. A finger passed along the base of the wound will aid in this. Subsequent packing should be carried to the depth of the wound, but inserted lightly. Frequently, after 2 to 3 weeks all packing is discarded. At these dressings, the thread is grasped with the forceps and moved to and fro slightly, to prevent it from adhering to the tissues in contact with it. If for any reason it is desired to change the seton, this may be accomplished by tying a ligature above the knot of the seton *in situ*, cutting on the opposite side of the knot and, as the old one is drawn out, the new one is pulled into place.

The extensive dissection necessary in these operations has removed considerable tissue from the lateral and proximal (under) surfaces of the external sphincter. It has, thereby, been essentially deprived of a certain amount of its fixation. To sever the muscle at the same time would permit the cut edges of the muscle to retract and even to dip somewhat into the open wound. Since several weeks are required for the wound to fill in and heal, the muscle ends become adherent to and

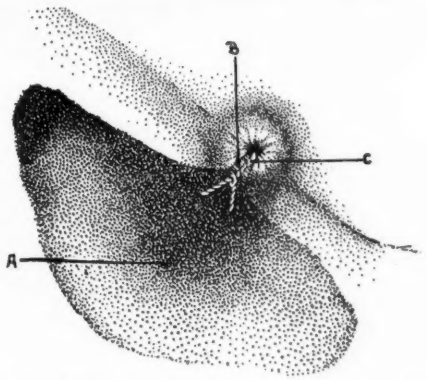


Fig. 1. Schematic drawing showing the relation of the seton to the muscle fibers and operative wound. *A*, Extensive cavity after dissection of fistulous tracts and their removal as far as bowel wall. *B*, Fibers of external sphincter muscle exposed. *C*, Heavy silk ligature, the seton, passing into anal canal, through internal opening, and out into wound, then tied in place to surround sphincter muscle. If internal opening is above the internal sphincter, the ligature will surround both muscles.

embedded in the wound. No degree of union of the edges could be expected, and, in addition, a deep sulcus may remain in the course of the sphincter fibers. The muscle ends are fixed in a mass of scar tissue, but, because of the deformity, this scar tissue often does not provide enough anchorage for the muscle to pull against and partial or even complete impairment of its function will result. The rôle of the external sphincter in maintaining anal continence has already been mentioned.

As the wound heals and the cavity fills in, it will be noted that the spaces on the under and lateral surfaces of the sphincter have been replaced by scar tissue. The muscle now is well supported, probably more firmly than before operation. When the filling-in process is complete, there remains only a small sinus, the bed of the "seton." This tract extends actually only under the muscle, from its external margin. The patient is now ready for the second stage of this procedure, i.e., severing the sphincter muscles (Fig. 2).

The tissues immediately surrounding the ligature, as well as those encircled by it, are infiltrated with novocain in 1 per cent solution and a small curved, probe tipped grooved director is inserted through the tract, from its external through its internal margin. Then the muscle fibers overlying it are severed from above downward. This enables the operator to be exact in making the incision at a right angle to the fibers. The base of the tract is gently curetted and any small bits of mucosa or

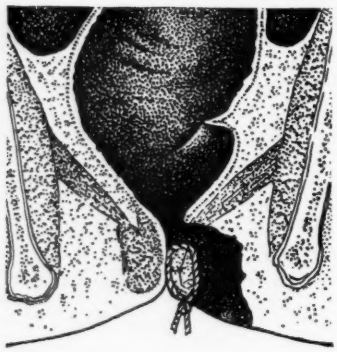

Fig. 2. Schematic drawing of a transverse section to show the relation of the seton to the tissues of the anal canal. The ligature surrounds both external and internal sphincter muscles with the internal opening of the fistulous cavity superior to the latter muscle. The mucosa and skin covering the sphincter have been incised so that ligature surrounds only the muscle fibers.

granulation tissue that overhang the wound edges are cut away. A thin strip of packing is inserted into the wound, which is usually not over a half inch deep in its greatest diameter. Because of the firm support to the muscle, the severed ends separate very slightly, or they may remain practically in contact with each other. In either case, it is necessary to pass a swab to the base of the wound so that healing takes place from the bottom. Healing is complete in about 2 weeks.

The muscle ends may unite directly, but, as a rule, they are joined together by a thin partition of scar tissue. Union is usually quite firm and there is little deformity in the contour of the muscle. As a result, function is practically normal. By not allowing the ends of the severed muscle to remain widely separated for a period of weeks, during which these ends may become embedded in the edges of the operative wound, and by delaying severance of the muscle until it is firmly supported so that its severed ends are kept in place, we find that good union without deformity, with good function can be achieved.

It may be claimed that this two stage procedure can be carried out as satisfactorily without the use of the silk or linen ligature, the so called "seton." This has not been found true in practice. The seton serves primarily to identify and to keep patent the internal opening until it is ready to be dealt with. When not used, the mucosa may close over the internal opening, as a result of the adequate drainage distal to it. Then, when the muscle is ready to be severed, the original internal orifice cannot be accurately determined. Careful dissection will then be necessary to locate it, for the importance of eradicating this focus is apparent. This closing over of the internal opening may be deceptive in that it will suggest that this portion of the fistulous tract has healed. But the small tract under the muscle will still be present and serve as a focal point for the development of another fistulous process. The seton, therefore, is of value not only in locating the internal opening for the second stage of operation, but permits this second step to be done with ease, and, as pointed out, will allow us to transform the direction of the tract when occasionally necessary so that the muscle can be severed at right angles to its fibers.

SUMMARY

The importance of the external sphincter in maintaining anal continence is pointed out. The necessity for avoiding deformity with impairment of function of the sphincter muscles following operation for anorectal fistula is emphasized. The operative technique for a two stage operation for anorectal fistula is described in which the muscles are not severed and the internal fistulous opening not dealt with until the second stage. Good union of the muscle ends without deformity and with good sphincteric function was thereby achieved in 119 patients thus treated.

BIBLIOGRAPHY

1. Bickham, Warren S. Operative Surgery. Vol. v, p. 183. Philadelphia: W. B. Saunders & Co., 1924.
2. Buie, L. A. Surg. Clin. N. America, 1927, vii, 1579.
3. Drueck, Charles John. Fistula of the Anus and Rectum. Philadelphia: F. A. Davis & Co., 1927.
4. Edwards, F. S. Lancet, 1918, May, 673.
5. Gant, S. G. Diseases of the Rectum, Anus, and Colon. Vol. i, p. 332. Philadelphia: W. B. Saunders & Co., 1923.
6. Hiller, R. I. Surg., Gynec. & Obst., 1931, lii, 921.
7. Hirschman, Louis J. Handbook of Diseases of the Rectum. St. Louis: C. V. Mosby Co., 1923.
8. Matti, Hermann. Quoted by Hiller. Deutsche Ztschr. f. Chir., 1909, ci, 70.
9. Martin, Collier F. Am. J. Surg., 1925, December.
10. Pennington, J. R. Rectum, Anus and Pelvic Colon. P. 619. Philadelphia: P. Blakiston & Co., 1923.
11. Sistrunk, W. E. New Orleans M. & S. J., 1928, lxxx, 515.

# DIAGNOSIS AND TREATMENT OF CIRCULATORY DISTURBANCES OF THE EXTREMITIES[1]

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PROGRESS in the field of peripheral vascular diseases can be expected only when adequate methods for testing peripheral circulation are systematically employed and when the value of various therapeutic procedures can be estimated not only by the subjective and often suggested impressions of the patient, but by objective functional tests. It is the purpose of this paper to give an outline of such methods of examination and treatment that have proved to be of value, without attempting to cover the extensive and often confusing literature on the subject. The material up to date consists of 100 cases of proved peripheral vascular disease and does not include a great number of examinations on patients in whom peripheral circulatory disturbance was suspected but not detected.

## OUTLINE OF EXAMINATION

When a patient's complaints, such as cold hands and feet, pale cyanotic or hyperæmic extremities, tingling and numbness of the acra, burning and freezing, cramping on walking or at night, suggest a circulatory disturbance, a systematic investigation of the peripheral vascular status is indicated.

*The peripheral pulse* is estimated on the basis of three. It is palpated at the dorsum of the foot, at the inner ankle, in the popliteal fossa and below Poupart's ligament in the lower extremity. In the upper extremity, the digital pulses, those of the radial, ulnar, and cubital arteries and finally the subclavian artery are sought. A difference of symmetrical pulses is significant and may mean an aneurism, an arteriovenous fistula or a partial or total vascular occlusion in the periphery. Absence of pulse may be present immediately after a severe injury to a limb, but does not necessarily mean injury or thrombosis of the main artery. Such segmental spasms of large vessels, chiefly the femoral, have been described by Kuettner. One of us has seen several cases in the World War on the Serbian front. The spasm is relieved by heat within a few hours and the cold pallid limb may regain its normal appearance.

Absence of pedal pulses is not infrequently present in older patients, overwhelmingly men, who suffer from peripheral arteriosclerosis. Such patients may have no complaints at all and their feet are warm. Adequate collateral circulation had developed during a slow, gradual occlusion of the main vessel. From a standpoint of function, their peripheral circulation is compensated. An absence of pulse does not necessarily mean that no blood is carried in that vessel, as a rigid, calcified vessel, unable to transmit a pulse wave, may still permit an even trickling of blood to the periphery.

*The surface temperature* is estimated at various levels of the limb, either with a thermocouple galvanometer or with a mercury skin thermometer. The latter is sufficient for practical purposes. Absolute values are meaningless as so much depends on room temperature, amount of perspiration and outside temperature. Measurements should be taken, if possible, in a room not warmer than 22 degrees Celsius (70 degrees Fahrenheit), as otherwise the warm room will simply transmit its temperature to a cold extremity. Excessive perspiration, a frequent sign of increased sympathetic irritation, lowers temperature by increased loss of heat. The value of skin temperature readings is limited to (1) sudden drop in temperature of one extremity as a sign of inadequate arterial inflow. This can be well estimated with the palm of the hand, which easily detects differences larger than ½ degree centigrade, (2) marked differences between the temperature of symmetrical areas on two extremities, (3) a rise in temperature after various diagnostic measures, which aim to relieve vaso-constriction such as typhoid vaccine and novocain block.

*Postural changes of color.* Dependent rubor and pallor on elevation, furthermore pallor on exercising the elevated foot (18) are a sign of diminished arterial inflow to the capillary bed. Older patients, however, may have a dependent rubor on standing, without any serious disturbance of circulation.

*The cutaneous histamine reaction.* One of us evaluated this method elsewhere (6). When histamine acid phosphate is injected intradermally, not more than 0.1 c.c. being used at a time, a characteristic vasodilation occurs around the wheal: the arterial flare. The flare is due to a reflex vasodilation of the arterioles and is absent when (1) there is not enough pressure in the skin vessels to fill up the dilated arterioles,

[1] From the Peripheral Circulatory Clinic, Department of Surgery, Northwestern University Medical School.

(2) when an arterial spasm exists, which the histamine cannot overcome, or (3) when the cutaneous nerves have degenerated following peripheral nerve injury. Introduced as a routine measure in patients with manifest or suspected peripheral vascular disease the test gives the following information:

1. In patients with frank gangrene the lowest level of safe amputation is determined, although a normal histamine response only guarantees the status of cutaneous circulation. Circulation of bone may be impaired at the same level.

2. The improvement or standstill of the peripheral circulatory status can be determined during the course of conservative treatment.

3. In a beginning embarrassment of arterial inflow, the delay or absence of the histamine reaction around the ankle gives an early warning.

4. In vascular spasms the reaction is negative, but such reactions may be made positive by any measure that is known to relieve vessel spasm. These will be discussed a little later.

*The oscillometer.* Pachon's oscillometer, when the readings are charted according to our method (Fig. 1) determines the narrowing or occlusion of the main vessels. The shape and height of the curve determined at different levels of the same extremity and compared with readings at symmetrical levels of the other extremity gives an exact picture of arterial inflow through the larger arteries. Readings taken above and below aneurisms or above and below arterial occlusions demonstrate the amount of inflow and the site of the lesion. Contrary to the histamine test, the oscillometer does not determine the extent of collateral circulation.

*Roentgenological examination.* Flat plates reveal calcification of peripheral vessels, the extent of which is sometimes surprising, compared with the lack of clinical signs and symptoms. The chief enemy of the adult diabetic, arteriosclerosis, can be demonstrated early in juvenile diabetics (21). But such findings do not determine the adequacy of circulation and can be used only as an adjunct in determining the peripheral vascular status. Much more information can be gained by visualizing blood vessels after the injection of opaque substances such as iopax, skiodan, or thorotrast (Fig. 2). In our work the first two substances have been used. The indications should be limited (1) to aneurisms, both traumatic and congenital, when the size of the sack, the site and number of communications and the development of collateral circulation can be visualized and helps to outline the plan of operation; (2) to patients with marked organic obstruction as in certain stages of Buerger's disease, when the idea of sympathectomy might have to be abandoned because of the extent of organic vascular stenosis; (3) to cases of peripheral embolism, to determine the exact site of the embolus, if otherwise undetermined.

*Examinations not routinely employed* but which may prove to be very valuable in certain patients are:

1. Electrocardiogram, which is taken before every sympathectomy.

2. Blood volume and blood viscosity, when polycythæmia is suspected. Blood volume may differentiate between an early polycythæmia and Buerger's disease. In the latter the blood volume is below normal.

3. Ophthalmoscopy. The status of retinal vessels may give a valuable indication as to the status of the peripheral vascular system.

4. Plethysmograph, constructed by Johnson, which may prove of great value in clinical research problems.

5. Biopsies of smaller arteries of the hand and foot which may reveal characteristic histological changes.

### DIFFERENTIATION OF ORGANIC AND SPASTIC VASCULAR OCCLUSIONS

In a previous paper (7) the various methods employed were discussed and we will present only the ones actually employed now in our work. As it is known that the vasoconstrictor fibers to an extremity run in the peripheral nerves, a novocain block of these nerves will release the arterial tree from all central vasomotor influence. In the lower extremity, the posterior tibial nerve is blocked at the inner ankle and the skin temperature of the plantar surface of the big toe is determined before and 10 minutes after the injection. Table I, taken from a previous communication, illustrates the figures which may be obtained and their interpretation. In painful, vasospastic amputation stumps, the femoral or sciatic nerves have been successfully blocked. On the upper extremity, according to the involved areas, the ulnar, the median nerve, or the brachial plexus have been blocked and the increase in surface temperature to the normal vasodilation level of 33–35 centigrade was determined.

As most of our patients are ambulatory, tests with typhoid vaccine, spinal or paravertebral anæsthesia have not been employed. Besides, these methods are open to criticism.

The use of vasodilator drugs such as theobromin, anylnitrite and acetylcholine as a therapeutic test is well established but does not give such

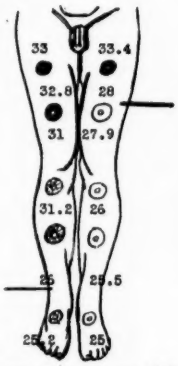
PERIPHERAL CIRCULATORY RECORD

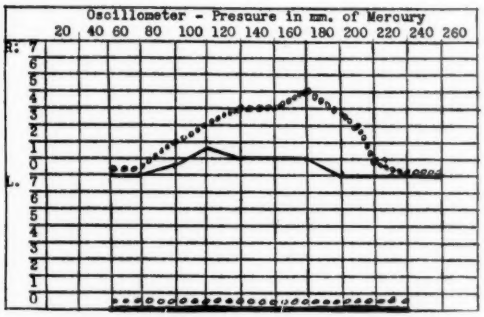
Name Mrs. G. K. Age 63
Skin temperature Sudden drop at upper third of left thigh
Diagnosis: Diabetic gangrene
Blood pressure 160/90
Blood volume —
Blood count —
Blood viscosity —

| Pulse | Right | Left |
|---|---|---|
| Popliteal | 1 | 0 |
| Post tibial | 0 | 0 |
| Dorsalis pedis | 1 | 0 |

| Histamine test On basis of 0 to 3 | Right | Left |
|---|---|---|
| Above knee | 3 | 0 |
| Below knee | 2 | 0 |
| Middle of calf | 2 | 0 |
| Ankle | 1 | 0 |

Other findings
Right Left




Temperature of left big toe:
Before novocain block 25° C
After novocain block 26.2° C
Obstruction index: 33 − 26.2 = 6.8

——Below knee
oooo Above knee

Room temperature 25° C.

Résumé: Organic vascular obstruction with hardly any superimposed spasm. Skin temperatures and histamine flares indicate level of amputation on left at upper third of thigh. Right leg painless but is in danger of future gangrene.

Fig. 1. Record used in the Peripheral Circulatory Clinic, Northwestern University Medical School. Blood volume, blood counts and blood viscosity are determined in cases suspicious of polycythæmia. A majority of patients, afflicted with Buerger's disease, have high red counts, high viscosity of the blood and low blood volume. Pulse and histamine reaction are estimated on the basis of three. The oscillometric readings are plotted on a graph and give much more information than the customary oscillometric index. The graph indicates the size of oscillations (vertical figures), plotted against the pressures in the upper cuff of the instrument, expressed in millimeters of mercury. In this patient, the oscillometric curve is fairly normal at the right thigh, very flat at the right ankle. No oscillations are present on the left leg, both below and above the knee. The skin temperature is expressed in centigrades, and measured with a mercury skin thermometer. The histamine flares are drawn in 3 degrees of intensity, marked, diminished, and absent. The temperature of the left big toe rose very slightly after the injection of 5 cubic centimeters of 2 per cent solution of procaine hydrochloride into the posterior tibial nerve. The maximum rise in temperature, deducted from the normal vasodilation level of 33° C. (Morton and Scott), gives a high obstruction index of 6.8. The graph illustrates the method of determining the peripheral vascular status on an ambulatory patient.

an accurate idea of the spastic element as the nerve block. The effect of heat on oscillometric readings or histamine response is another possible approach to the problem, which we have occasionally employed.

### DETERMINATION OF THE PROPER LEVEL OF AMPUTATION

It is not within the scope of this paper to discuss the indications for amputation. Instead we wish to emphasize our methods for arriving at a deci-

TABLE I.—DIAGNOSTIC VALUE OF POSTERIOR TIBIAL BLOCK

| | Number of cases | Average rise in temperature | Average obstruction index |
|---|---|---|---|
| Group I | 10 | 7 C. | None |
| Group II | 10 | 1.5 C. | 5 |
| Group III | 10 | 4 C. | 3 |

Group I—Patients with cold feet, good pulse, pure spasm, no obstruction.

Group II—Patients with organic occlusions, no, or hardly any, superimposed spasm.

Group III—Patients with organic occlusion and considerable spasm.

Obstruction index (Morton)=normal vasodilation level (33° C.)—maximal temperature obtained after nerve block.

The use of peripheral nerve block for differentiating spastic from organic occlusions. Occasionally, when marked spasm occurs *above* the level of nerve block, the vasodilation *below* the injection will not represent maximal vasodilation. In such patients nerve blocks have to be performed at a higher level.

TABLE II.—CLASSIFICATION OF PERIPHERAL VASCULAR SYNDROMES

| | |
|---|---|
| A. Organic lesions | |
| 1. Congenital anomalies | 12 |
| 2. Injuries | 12 |
| Traumatic, aneurism, thrombosis | 3 |
| Thermic, frost bite | 3 |
| Chemical, lead, arsenic | 4 |
| Electrical | 1 |
| Radium and X-ray | 1 |
| 3. Infections | 27 |
| Thrombo-angiitis obliterans (Buerger) | 20 |
| Rheumatic infection | 2 |
| Lues | 3 |
| Tuberculosis | 1 |
| Paratyphoid | 1 |
| 4. Degenerative processes | 17 |
| Peripheral arteriosclerosis | 15 |
| Diabetic endarteritis | 2 |
| Endstage of inflammatory reactions. | |
| Total | 68 |

| | |
|---|---|
| B. Functional disturbances | |
| 1. Vascular spasms | 26 |
| Primary, idiopathic (Raynaud) | 5 |
| Secondary arterial spasms: | |
| Tabes, syringomyelia, spastic hemiplegia and poliomyelitis | 2 |
| Cervical rib | 1 |
| Osteoarthritis of spine | 2 |
| Spina bifida occulta | 2 |
| Traumatic perineuritis | 1 |
| Polyneuritis | 1 |
| Amputation-neuroma | 3 |
| Stonecutter's spastic anæmia | 1 |
| Early intermittent hypertension | 3 |
| Endocrine disturbances | 5 |
| All organic changes with superimposed spasm. | |
| 2. Vasoparalytic phenomena | 6 |
| Erythromelalgia | — |
| Polycythæmia | 2 |
| Compensatory erythrocytosis | 1 |
| Acrocyanosis | 3 |
| Total | 32 |

sion as to the site of amputation. There has been much confusion and uncertainty on this point.

When an amputation is decided on, we systematically employ the tests described, the pulses are palpated, surface temperatures are read, the oscillometer and histamine reaction are employed. Most useful are the surface temperatures and the histamine reaction, the results of which coincide most often (Fig. 1). Oscillometric readings would generally indicate a higher occlusion of the main vessel, but this is easily explained by the development of a sufficient collateral circulation distal to the occlusion. Thus, for instance, in midthigh amputations the femoral pulse is often absent, the oscillometric readings are zero at the upper third of the thigh, but the skin temperature readings and the histamine response clearly indicate a sudden change in circulation at a certain level on the thigh.

A negative histamine flare is mainly useful in insuring us against too low amputations, while a positive flare may not insure us of enough circulation to take care of the healing of the stump. One must also know that circulation in the bone, not subjected to the beneficial action of muscular massage is often impaired at a somewhat higher level, as proved by injected specimens (4).

In spite of the fact that we have amputated just as low as possible, with the help of these tests not one single reamputation was necessary during the last 3 years. Another interesting fact was the frequent finding of infectious gangrenes due to osteomyelitis of the toes in diabetics, as first stressed by McKittrick and Root. These patients do not require an amputation at all, as the gangrene is not on a circulatory basis, and conservative treatment, with minor amputations is often successful.

### CLASSIFICATION OF PERIPHERAL VASCULAR SYNDROMES

Table III gives a working classification of these disorders. Obviously, with increased knowledge on the subject, certain essential, "primary" lesions will be grouped with the syndromes of known etiology. It must be also emphasized that organic lesions will almost invariably produce superimposed functional disturbances and that vessel spasm, if repeated too often, will undoubtedly bring about organic changes. With the help of the tests described, it is possible to differentiate the organic from the spastic element.

*A. Organic lesions.* The first group of organic lesions, the congenital anomalies, have been studied and described in detail (8). Our material now consists of 12 cases. Early recognition and radical surgery offer the best hope for cure. In most cases, there are abnormal arteriovenous communications, which are too narrow to give any thrills. Early recognition depends on (1) increased surface temperature of the affected side; (2) hemihypertrophy of the affected limb (not always present); (3) the presence of mixed (arteriovenous) blood in the vascular dilatations, which may be recognized by the color of the blood or exactly by determinations of oxygen content with the Van Slyke apparatus. The visualization of blood vessels of the affected side may lead the

TABLE III.—VASCULAR ANOMALIES (12 CASES)

| Case | Age Sex | Diagnosis | Duration | Symptoms | Treatment | Result |
|---|---|---|---|---|---|---|
| 71014 Ev. Hos. | 58 F. | Multiple arteriovenous fistulæ of hand | Noticed since age of 12 | Swelling, dilated veins, pain in arm and hand; hand useless | Excision of vascular mass | ++++ Hand useful |
| H. L. | 21 M. | Phlebectasia of wrist and forearm | Noticed at age of 13 | Progressive dilatation of veins at wrist; dull ache on exercise | Excision of anomalous vessel | ++++ |
| J. de F. | 20 M. | Hæmangioma of right half of scrotum, buttocks, thigh and calf | Noticed at age of 5 | Progressive dilatation of vascular masses; swelling, pain, cyanosis | Excision and obliterative injections | +++ There are a few remaining dilatations; function normal |
| A. D. | 16 F. | Congenital vascular anomaly of left leg; large birthmark | Noticed at age of 10 | Swelling, repeated hæmorrhage from miliary aneurisms | Excision in three stages and obliterative injections | +++ Some residual cyanosis of toes |
| M. L. | 42 F. | Vascular anomaly left popliteal fossa | Ever since she can remember | Multiple spongy, vascular masses; pain; swelling | Complete excision | ++++ |
| H. Z. | 15 F. | Congenital vascular anomaly of face and orbit | Since birth | Progressive vascular dilatation; intermittent exophthalmos | Refused operation; radium treatment elsewhere | Unknown |
| W. E. L. | 24 F. | Congenital vascular anomaly of left foot, calf and buttocks | Since birth | Intermittent claudication; recurring phlebitis; progressive dilatation | Obliterative injections | Pain subsided; anatomic result + ; functional result +++ |
| L. B. D. | 51 M. | Congenital arteriovenous aneurism, right leg | Noticed at age of 19 | Ulcer; huge indurative œdema. Right leg larger than left. | Excision of aneurism | Anatomic result +; functional result ++++ |
| A. A. | 50 F. | Multiple angiomata of lips and tongue | 10 years? | Swelling, bleeding, gradual spread | Multiple obliterative injections | ++++ |
| L. de B. | 32 F. | Phlebectasia of superficial veins of neck | ? | Spontaneous thrombosis; capillary dilatation | Excision | ++ Some recurrence of vascular dilatations |
| C. R. | 31 M. | Multiple arteriovenous fistulæ of left leg | Since birth | Elephantiasis; dilated vessels; cyanotic toes | Excision followed by injections | +++ Some residual swelling |
| A. C. | 28 F. | Arteriovenous fistula left foot | ?, possibly started with trauma | Swelling; increased temperature; ulcer on dorsum of foot; venous pulsation | Excision of arteriovenous fistula | ++++ |

surgeon to a direct attack of the anomalous communications. Radical excision may be supplemented, if necessary, with obliterative injections.

In the second group, the word *injury* has been used in a more general sense. Frost bite, even though the initial injury may seem to localize only in one finger or toe, frequently produces endothelial changes in the vessels proximally to the acra. Thus, patients' extremities, if amputation becomes necessary, are removed far too low, and several reamputations are usually made before the adequate level is reached. Histologically, cushions of cellular masses, a true granulation tissue, accumulate below the endothelium, produce damage of vessel permeability and are responsible for all other changes such as medial œdema, perivascular reaction, thrombosis, and perineuritis (10, 11). This vascular reaction is the typical response of the vessel wall to all other forms of injury, electric, chemical, bacterial, or allergic, and it is for this reason that the histological picture of Buerger's disease is so similar to that of frost bite. That these organic changes can again produce reflex vascular disturbances is most likely, and thus a vicious circle is established.

Burns, but particularly electric discharges, may produce vascular damage, which is hardly estimable at the time of injury. Thus an electric current may simply roll up the intima of a large vessel and produce thrombosis at a distance. A repair man on an elevated line, who received repeated electric shocks and, in addition, worked in extremely cold weather without gloves, showed a marked obliterative endarteritis of the fingers.

Vascular damage due to lead or arsenic is not well known, but does occur since "moonshine" liquor frequently contains both metals. Our material contains 4 cases of this sort.

We shall skip the discussion of traumatic thromboses, aneurisms and pressure necrosis, as little of new data has accumulated on the subject. Blood vessel visualization, however, has added a great deal to the rapidity and ease with which these formidable surgical problems can be attacked. The amount of collateral circulation following compression of the proximal feeding vessel, must be studied before a permanent arterial ligature is undertaken.

TABLE IV.—VASCULAR INJURIES (11 CASES)

| Case | Age Sex | Diagnosis | Duration | Symptoms | Treatment | Result |
|---|---|---|---|---|---|---|
| 22989 | 24 M. | Arteriovenous aneurism, midthigh | 6 weeks | Swelling, bruit, venous pulsation | Endo-aneurismorrhaphy | +++ Slight swelling and cyanosis |
| 508901 | 40 F. | Thrombosis of iliac artery following venous thrombosis | 5 years | Diminished pulse, temperature; pain, claudication | Physiotherapy; elastic support; salicylates and iodides | ++ |
| H. H. | 55 F. | Thrombosis of femoral artery following deep venous thrombosis | 3 years | Pedal pulses absent; dependent rubor; left leg swollen, cold | Physiotherapy; ammonium chloride and salyrgan | + Swelling improved; no improvement of arterial circulation |
| 15624 | 33 M. | Frozen fingers, left hand | 2 years | Blanching; stiff joints; diminished pulse | Physiotherapy | + Slow improvement |
| H. P. | 46 M. | Frozen fingers and toes | 2 days | Swelling, blisters, absent digital pulsations | Continuous heat; protective dressing | Amputation of two fingers −* |
| 54369 | 56 M. | Frost bite. Bilateral amputation 8 inches below knee | 5 years | Cold stumps; decubital ulcers; claudication | Bilateral lumbar sympathectomy | Left stump −* Right stump +++ |
| C. S. W. | 63 M. | Obliterating endarteritis; 0.8 mgr. lead in 24 hour urine | 4 years | Pain, color changes, numbness and tingling | Stopped alcohol; Aub's diet | No improvement. Died one year later of cerebral hæmorrhage |
| 44538 | 27 M. | Vascular spasm lower extremities; prolonged exposure to lead | | Sudden drop of temperature at knee; tingling, numbness; urine+lead | Aub's diet; physiotherapy | +++ Almost completely relieved; may have some organic damage |
| 50527 | 42 M. | Vascular spasms; chronic lead poisoning | | Numbness and tingling of symmetrical areas; hands generally warm | Elimination of exposure to lead | +++ |
| W. P. V. | 43 M. | Vascular spasms; 5.0 mg. arsenic in 1000 c.cm. of urine | 6 months | Spasm in calves, numbness and tingling | Eliminated spray containing arsenic; physiotherapy; vasodilators | +++ Practically free of symptoms |
| H. W. | 47 M. | Repeated electric shocks; exposure to cold; excessive smoker. Repairman on elevated lines | 1 year | All fingers except thumb numb and painful; sensitive to cold | Physiotherapy and vasodilators | Could not be followed |

*Results graded on the basis of − to +++.

The third group of *inflammatory* vascular reactions is a most difficult subject. It has already been stated that the vessel wall always responds with the same type of reaction no matter what the original injury is. We have observed peripheral vascular disturbances due to syphilis, paratyphoid, rheumatic fever, and a very rare case of tuberculous arteritis in a colored girl; arteritis has been described in typhus fever, cholera, bacterial endocarditis, and streptococcus septicæmia. It is very probable that thromboangiitis obliterans, justly called Buerger's disease, will be gradually split up into diseases of known etiology and with it specific treatment will become possible. The rôle of ergot in producing peripheral vascular disease has also been re-emphasized (14). Any attempt to classify and separate these inflammatory arteritic reactions on a histological basis is of doubtful value as specimens gained at amputations or seldom through biopsy contain the vessels in a terminal stage of thrombosis, obliteration, and partial recanalization. Nevertheless, biopsies of smaller arteries often yield conclusive evidence of the specific nature of an arteritis. The endothelial proliferation, whether the infectious agent comes from the adventitia or from the blood stream, seems always the most important reaction. That some of these recurrent attacks of arteritis and phlebitis are on an allergic basis is very likely, as the small adventitial and subintimal patches of fibrinoid degeneration and granuloma have all the earmarks of hyperergic inflammation (12). Many of the so called cases of Buerger's disease may be rheumatic in nature. It has been our impression that vascular inflammatory reactions are usually seen in patients with hypoplastic vessels, lymphatics, asthenics.

*In the fourth group* of degenerative processes belong the senile arteriosclerotic and diabetic gangrenes and pregangrenous states. Most pathologists agree on a separation of atheromatous, intimal plaques from the types in which medial calcification is the primary lesion. The development of adequate collateral circulation will depend on sufficient cardiac reserve and collateral vessels capable of dilatation. A differen-

TABLE V.—INFLAMMATORY REACTIONS (26 CASES)

| Case | Age Sex | Diagnosis | Symptoms | Treatment | Result |
|---|---|---|---|---|---|
| 49173 | 36 M. | Buerger's disease | Pain on walking and rest, dependent rubor, absent pulses | Typhoid vaccine; stop smoking; vasodilators; physiotherapy | Improving under treatment |
| 21755 | 43 M. | Buerger's disease | Cold fingers and toes; ulcer on left index finger; weak pulses | Typhoid vaccine; vasodilators; physiotherapy | ++ Ulcer healed; skin still glossy, cold; in quiescent stage |
| 51047 | 46 M. | Buerger's disease | Arrest of circulation, both feet; very little spasm; blood volume low | Typhoid vaccine; postural exercise; diathermy; push fluids | + Heavy drinker; could not be followed |
| 38653 | 40 M. | Buerger's disease | Intermittent claudication, color changes; tenderness of arches; great deal of spasm | Typhoid vaccine. Physiotherapy; continuous baking at night | ++ Marked improvement; discontinued treatment |
| 43888 | 25 M. | Buerger's disease | Numbness and aching right index finger; small ulcer | Typhoid vaccine; continuous heat; stop smoking | ++++ Ulcer healed; pain disappeared; no digital pulse |
| 72144 | 50 F. | Buerger's disease | Numbness, pain, ulcer on medial aspect of tibia; spontaneous phlebitis | Heat, elevation; tonsillectomy; continuous baking | Did not return for follow-up |
| 36441 | 39 F. | Buerger's disease | Intermittent claudication; foot cold, pulse weak; no sclerosis | Vaccine; physiotherapy; vasodilators | ++ Still under treatment |
| 55962 | ? M. | Buerger's disease | Sudden drop of temperature at midthigh; intermittent claudication | Physiotherapy; vasodilators | ++ Amputation of two toes |
| 35485 +F | 25 M. | Buerger's disease | Dependent rubor; ulcer left big toe; rest pain | Vaccine; vasodilators; physiotherapy | No improvement; patient could not be followed |
| E. A. | 31 M. | Buerger's disease | Lost both legs below knee; pain, numbness in hands | Great deal of previous treatment; left cervicothoracic sympathectomy | Left side warm, painless; right unchanged |
| S. G. | 21 M. | Buerger's disease | Dependent rubor; great deal of spasm relieved by nerve block | Lumbar sympathectomy | Feet still cyanotic but painless; hands are getting involved |
| R. H. | 29 M. | Buerger's disease | Both legs previously amputated; sudden drop of temperature at left wrist; ulcer second finger | Continuous heat in bed; vaccines; vasodilators | ++ Marked improvement; ulcer healed |
| J. M. | 49 M. | Buerger's disease, beginning arteriosclerosis | Rest pain, sensitive to cold | Vasodilators; physiotherapy | Did not return; vaccine was not given |
| C. F. | 36 M. | Buerger's disease | Intermittent claudication; rest pain; poor pedal pulses | Vaccine; physiotherapy; vasodilators | ++++ Patient perfectly symptomless for three years |
| Th. G. | 59 M. | Buerger's disease; peripheral arteriosclerosis | Intermittent claudication; cold and numb toes | Physiotherapy; vasodilators | + Slight improvement |
| N. G. | 36 M. | Buerger's disease | Rest pain; no pedal pulses | Stop smoking; vaccine; physiotherapy | Could not be followed |
| J. F. | 43 M. | Buerger's disease | Dependent rubor; phlebitic patches; cold pulseless foot | Physiotherapy; vaccine; vasodilators | ++ Marked improvement, one year; new flare-up last winter |
| G. D. | 44 M. | Buerger's disease | Two toes amputated; rest pain; phlebitic patches | Vaccine; vasodilators; physiotherapy | Not seen since first visit |
| M. V. Th. | 38 M. | Buerger's disease | Pain in soles of feet; big toe ulcerated | Rest in bed three weeks; physiotherapy and vaccines | +++ Ulcer healed; pain subsided |
| S. V. | 30 F. | Rheumatic heart; rheumatic arteritis | Cold, pulseless foot; indolent leg ulcer | Salicylates; vaccine; physiotherapy | Still under treatment |
| A. S. | 45 F. | Rheumatoid arthritis in hands and feet; rheumatic arteritis | Pulseless foot; dependent rubor; claudication | Vaccines; physiotherapy | + Slight improvement in collateral circulation |
| A. B. | 42 F. | Luetic arteritis; luetic heart | Claudication; rest pain; dependent rubor | Antiluetic treatment, physiotherapy | Still under treatment |
| 48105 | 33 M. | Luetic ulcer of leg; arterial obstruction | Foot pulseless, cold; claudication | Antiluetic treatment, physiotherapy | ++ Ulcer healed; leg still painful |
| M. N. | 52 M. | Paratyphoid fever followed by popliteal hæmatoma; positive culture | No pedal pulse; dependent rubor; claudication | Autogenous vaccine; physiotherapy | +++ Greatly improved |
| A. J. | 18 F. | Pulmonary and joint tuberculosis; obliterating arteritis left big toe with self amputation | Sudden drop in temperature at midcalf; absent pulses | | |
| 36441 | 39 F. | Buerger's disease? | Claudication in left foot. Posterior tibial artery weak; skin glossy | Vaccine; physiotherapy; vasodilators | Not improved |
| 38068 | ? M. | Luetic arteritis; ulceration | Absent pulses on foot; large punched out ulcer | Antiluetic treatment | Ulcer healed. Arterial obstruction not improved |

TABLE VI.—DEGENERATIVE PROCESSES (17 CASES)

| Case | Age Sex | Diagnosis | Symptoms | Treatment | Result |
|---|---|---|---|---|---|
| Dr. E. R. | 57 M. | Peripheral arteriosclerosis; impending gangrene | Color changes; sudden fall in temperature; rest pain | Digitalis; continuous physiotherapy; vasodilators | + Slight improvement of circulation |
| 23537 +E | 64 M. | Arteriosclerotic gangrene | Ulcers of left heel and external ankle | Amputation advised | |
| 51592 | 71 M. | Arteriosclerotic occlusion | Cramps in calves, absent radial pulses, color changes | Physiotherapy; vasodilators | ++ Much improved |
| 46078 | 60 M. | Peripheral arteriosclerosis; hypertension | Left leg atrophic, cold, pulseless | Physiotherapy; vasodilators | + Subjective improvement |
| 53768+ | 74 M. | Calcified vessels; hypertension | No pulses below knee; toes warm; slight claudication | Physiotherapy; vasodilators | Good collateral circulation |
| 45786 +E | 48 M. | Peripheral arteriosclerosis | Numbness and tingling in toes; intermittent claudication | Did not return | |
| 35057+ | 49 M. | Peripheral arteriosclerosis; myocardial degeneration | Sudden drop in surface temperature; absent pedal pulses; scaly, atrophic skin | Digitalis; vasodilators; physiotherapy | + Slight improvement |
| 36107 | 79 M. | Hæmiplegia six months before; hypertension; impending gangrene | Cold, cyanotic feet; rest pain | Amputation above knee | +++ Useful stump |
| 58000 | 57 M. | Peripheral arteriosclerosis; hypertension | Intermittent claudication; absent dorsalis pedis pulse | Physiotherapy; vasodilators | Did not continue treatment |
| 19961 | 61 M. | Impending arteriosclerotic gangrene | Pain, cyanosis, drop in temperature | Vein ligation advised | Refused treatment |
| Ch. P. | 67 M. | Peripheral arteriosclerosis; hypertension | Drop in temperature; claudication; rest pain | Physiotherapy; vasodilators | Did not return |
| 49669 | 56 M. | Peripheral arteriosclerosis | Claudication; numb; cold feet | Physiotherapy; vasodilators | ++ Much improved |
| H. J. W. | 72 M. | Peripheral arteriosclerosis | Claudication; no rest pain | Digitalis; physiotherapy; vasodilators | + Slight improvement |
| B. A. D. | 72 M. | Obliterating endarteritis | Pulses good; no rest pain | Physiotherapy | +++ Marked improvement |
| 14734 | 61 M. | Peripheral arteriosclerosis; high grade osteoarthritis | Two gangrenous spots; swelling, cyanosis, cold stumps | Previously amputated. Physiotherapy, injection of neuroma | + Some improvement; left the city |
| J. M. D. | 63 M. | Prostatic hypertrophy, hypertension; peripheral arteriosclerosis | Pedal pulses absent; excruciating pain at night; cold toes | Alcohol injections left foot | Foot painless for 3 months; gangrene; amputation |
| A. H. | 70 F. | Diabetic endarteritis | No pulses below popliteal; marked rest pain | Bilateral amputation at midthigh | Lived 4 months; died of coronary thrombosis |
| H. P. | 56 M. | Diabetic endarteritis | Good pulses. Two gangrenous ulcers on foot | Rest in bed; physiotherapy; Thiersch grafts | Grafts took; leg serviceable in protective cast |

tiation of these degenerative processes from late stages of inflammatory reaction with scar formation is not always possible, particularly in older patients. From the standpoint of prognosis and treatment, however, the important point is whether the vascular obstruction is chiefly organic and irreparable or whether superimposed spasms are present, which may be relieved.

An important distinction must be made in the diabetic group between gangrenous states that are primarily due to obstruction of the larger vessels, and gangrenes due to infections, usually osteomyelitis of the toes. While the former group requires major amputations, the latter should be treated by incisions and wide drainage or minor amputations. Because of the frequent inflammatory reactions in diabetic tissue, surface temperature readings may be misleading. The histamine reaction is most useful to determine the level of circulatory insufficiency.

*B. Functional disturbances.* (1). *Vascular spasms.* The diagnosis of Raynaud's disease, a pure spastic occlusion of the digital arteries with unknown etiology should be made only when all secondary vascular spasms can be excluded. This is important not only because the removal of the primary factor may bring about a dramatic cure, but also because major operations on the sympathetic nervous system are unnecessary and do not result in cure in the secondary forms.

The transsection of the scalanus anticus muscle in patients with cervical rib (1), the freeing up of

TABLE VII.—VASCULAR SPASMS (RAYNAUD'S SYNDROME)—(26 CASES)

| Case | Age Sex | Diagnosis | Symptoms | Treatment | Result |
|---|---|---|---|---|---|
| [illegible]509 | 21 F. | Idiopathic vascular spasm | Intermittent blanching; numbness of fingers | Physiotherapy; cold training | No attack for 6 months |
| [illegible]328 | 29 F. | Vascular spasm; cutis marmorata | Hypersensitive to cold and mechanical stimuli | Physiotherapy; cold training | ++ Markedly improved |
| M. K. | 36 F. | Migraine headaches; vascular spasms in feet and hands | Tingling and numbness, chilly in third finger of both hands | Insulin; amyl nitrite | No change |
| A. McD. | 21 F. | Idiopathic symmetrical vascular spasm, all four extremities | Pain, coldness, terminal ulcerations, trophic changes | Lumbar sympathectomy advised | Did not return for operation |
| T. N. | 32 M. | Spastic occlusion; scleroderma | Terminal symmetrical ulcers; hidebound skin | Unilateral cervicodorsal sympathectomy | Vascular symptoms and pain improved; scleroderma unchanged |
| B. P. | 18 F. | Spastic occlusion of fingers and toes; rheumatoid arthritis | Coldness, tingling, blanching; swollen, clammy hands | Physiotherapy; vaccines | ++ Improved |
| C. Sp. | 45 F. | Osteoarthritis cervical spine; vascular spasm in fingers | Numbness, swelling, tingling of fingers; sensitive to cold | Physiotherapy; vaccines | Did not return for treatment |
| 45760 | 30 F. | Vascular spasm in fingers; bilateral cervical rib | Tingling and numbness in fingers; sensitive to cold | Operation advised | Did not return for operation |
| A. J. | 11 F. | Anterior poliomyelitis, unilateral vessel spasm | Cyanotic, cold extremity | Sympathectomy advised | Did not return for operation |
| 26922 | 38 F. | Spastic hemiplegia; marked vascular spasm; joint contractures | Pain, coldness, tingling; trophic ulcer at heel | Lumbar sympathectomy | Ulcer did not stay healed; amputation |
| 34961+ | 21 M. | Spastic occlusion both lower extremities; chiefly left; spina bifida occulta | Pallor of left foot, coldness, numbness; abnormal flushing of right foot | Exposure of spina bifida advised | Not operated on |
| 51554 | 18 M. | Vascular spasm; spina bifida occulta (first sacral segment) | Intermittent claudication, increased perspiration | Lumbar diathermy | +++ Marked improvement |
| 47559+ | 50 M. | Amputation neuroma; foot crushed 2 years ago | Cold, painful stump; trophic ulcer; no sequestrum | Physiotherapy; operation advised | ++ Pain relieved; stump still cold |
| J. G. | 45 M. | Amputation of left foot for crushing injury; amputation neuroma | Cold, painful stump; throbbing at night | Neuroma injected with alcohol | ++++ Relief lasting over 6 months |
| H. F. | 38 M. | Amputation left lower leg for injury; marked vascular spasm to knee; amputation neuroma | Cyanotic, cold stump, which warms up after novocain block | Excision of neuroma advised | Amputated at Cook County Hospital; neuroma verified |
| V. B. | 40 F. | Soft tissue injury to forearm; traumatic perineuritis of median nerve; secondary vessel spasm | Glossy, cold fingers; sensitive to cold; novocain abolishes all spasm | Physiotherapy | ++ Steady improvement |
| 55532 | 48 F. | Vascular spasm lower extremities; frostbite; endocrine disturbance | Attacks of blanching followed by cyanosis; early menopause; basal metabolism rate −20 per cent | Thyroid extract, gr. v, later gr. iii | +++ Circulation markedly improved; no further attacks of spasm |
| 54529 | 44 F. | Vascular spasm; endocrine disturbance | Pain in calves and ankle; left leg much colder, basal metabolism rate −18 per cent; preclimacteric symptoms | Thyroid, gr. iii | +++ No further spasms; toes warm |
| 36238+ | 29 F. | Vascular spasm; pitting œdema to knees; endocrine (pituitary?) | Cyanotic, œdematous legs; increased blood volume; normal basal metabolism rate; normal sella | Ammonium chloride; salyrgan | ++ Œdema temporarily improved; general condition the same |
| 50508+ | 14 F. | Vascular spasms; endocrine disturbance | Amenorrhœa 5 months; cold, cyanotic extremities; basal metabolism rate −14.8 per cent | Thyroid, gr. iii | +++ Greatly improved |
| 54815 | ? F. | Vascular spasms; parathyroid disturbance? | Cyanosis fingers and toes; basal metabolism rate and blood sugar normal; blood calcium 11.6 mgms.; decalcified bones in hand | | |
| 53290 | 32 M. | Vascular spasms; polyneuritis; vitamin deficiency?; starvation | Cold, vasospastic extremities; tingling, cramping | Balanced diet | Did not return |
| S. W. D. | 42 M. | Vascular spasms; early hypertension | Cold extremities; spasms in calves; pain at night | Vasodilators | Not seen again |
| G. G. | 63 M. | Vascular spasms; anginoid attacks; hypertension | Burning and pain in calves and feet | Vasodilators; sedatives; physiotherapy | + No marked relief |
| E. A. | 53 M. | Vessel spasms; spastic hypertension | Leg feels heavy and numb; cramp in calves | Physiotherapy; vasodilators; vacation | Unable to relax; no improvement |
| C. S. | 33 M. | Stonecutter's spastic anæmia | Vessel spasm of left fingers—only in winter | Physiotherapy; cold training; no work with air-hammer | Not re-examined |

TABLE VIII.—VASOPARALYTIC PHENOMENA (6 CASES)

| Case | Age Sex | Diagnosis | Symptoms | Treatment | Result |
|---|---|---|---|---|---|
| 34036+ | 49 M. | Polycythæmia vera; hypertension | Pain, rubor, claudication, burning; increased blood volume; increased viscosity | Phenylhydrazine | Claudication improved; died later of cerebral hæmorrhage |
| A. Gl. | 52 M. | Polycythæmia vera; hypertension | Red, painful acra; increased blood volume and viscosity; large spleen | Phenylhydrazine | Died one year later of cerebral hæmorrhage |
| E. Ei. | 65 F. | Compensatory erythrocytosis; pulmonary fibrosis; symptomatic erythromelalgia | Good pulses; burning pain relieved by cold; high blood count and hæmoglobin | Deferred treatment | |
| J. D. | 21 M. | Acrocyanosis; pituitary dysfunction? | Good pulses; cold, purple hands; no pain | | |
| 34734+ | 37 M. | Acrocyanosis; cutis marmorata | Cold, numbness in cyanotic areas; basal metabolism rate −7.8 per cent | | |
| B. J. | 22 F. | Acrocyanosis; cutis marmorata; endocrine disturbance | Four weeks after childbirth numbness and mottling appeared on the lower extremities; oligomenorrhœa. | Pituitary extract | Still under treatment |

the cauda equina and the roots in a spina bifida occulta (9), relieve vascular spasms of the extremities. Pre-operative novocain block with temporary relief from spasm in the affected parts gives the best indication for the relief to be expected.

Tabes, syringomyelia, sclerosis multiplex should be excluded from the possible causes of an angiospasm. Spastic hemiplegia and anterior poliomyelitis show, in some cases, a marked vascular spasm, relieved by peripheral nerve block. A traumatic perineuritis, following fractures or even mild contusions, produces painful circulatory disturbances. An amputation-neuroma is responsible quite often for the cold cyanotic stumps, which are so often unnecessarily reamputated. Any localized vascular disease, arteritis, arteriosclerosis, thrombosis, may produce an additional spasm of the vessel, simulating, sometimes, a purely functional disturbance. Of the endocrine disturbances, a low metabolic rate with some other evidence of hypothyroidism has been found not infrequently in women around the menopause. Possibly a pluriglandular hypofunction is at play; but thyroid medication is remarkably efficient in relieving these spasms and warming up cold hands and feet. The spastic anæmia of stonecutters, which occurs as a result of the vibration of the air-hammer (3000–5000 a minute), cramped position of fingers and, in addition, a prolonged contact with a cold tool, is not infrequently seen in the Indiana limestone district (5). We have observed one such case. Intermittent attacks of cramps in the musculature of the calf in excitable, high strung individuals may be one of the early signs of intermittent hypertension. The reaction of patients of such a temperament to adrenalin, heat or constriction of the arm is frequently inverted (20).

We have enumerated only such secondary vascular spasms as have come under observation; there may be more. But an effort should be made to exclude all known etiological factors before the diagnosis of a true Raynaud's disease is made. The situation here is similar to that discussed previously in connection with Buerger's disease. With increasing knowledge of specific causative factors, the idiopathic syndromes become more and more infrequent.

2. *Vasoparalysis.* The same observation applies to erythromelalgia, a very rare disease (31). Our 3 cases all had a polycythæmia and thus are secondary vasodilatations. Characteristic of erythromelalgia are the attacks of burning sensation in the presence of increased temperature of the acra, which is relieved by elevation and cold baths, but greatly aggravated by heat. The diagnosis of acrocyanosis, a syndrome poorly understood, but supposedly due to a paralysis of small veins with intact arterial inflow, was made in 3 cases.

The classification given may need revision from time to time. It serves its purpose by outlining therapy, which is sometimes etiological, but more often, because of our meager knowledge of the causative factors, simply symptomatic.

### TREATMENT OF PERIPHERAL CIRCULATORY DISTURBANCES

In the congenital type of arteriovenous fistula early radical operations, preferably done in several stages under regional anæsthesia, have been successful in our experience; but late cases show such irreparable damage to the tissues that permanent œdema or even gangrene cannot always be averted.

In burns, frost bite, and electric injuries, unless acute spreading infection is present, the greater

conservatism is indicated. Efforts to increase collateral circulation should be promptly instituted.

In metallic poisoning by lead or arsenic, the established methods used in freeing the body from these substances have shown remarkable improvement in the vascular changes.

In traumatic aneurisms, the obliteration of the sack with temporary or permanent proximal ligature seems the safest procedure. Complete excision of the sack with end-to-end arterial suture, sacrifices too many collaterals. Our experience during the World War with the latter procedure, was not favorable.

Inflammatory reactions, if a specific agent can be found or if autogenous vaccines are available, are treated etiologically.

In Buerger's disease, with its unknown etiology, non-specific foreign protein therapy is still the most efficient treatment. Whether it should produce some reaction and fever as originally suggested, or whether small, subreactionary doses are sufficient, is debatable. In addition, factors that aggravate vasomotor changes, such as nicotine, cold, psychic insults, are possibly eliminated. The disease has all the clinical and histological earmarks of a hyperergic inflammation; before this subsides no surgical therapy should be instituted. Infected teeth and tonsils are removed, not so much to influence the process in the vessel, but to prevent further sensitization. A generous use of vasodilators, chiefly theobromine with luminal, often gives subjective relief. Physiotherapy, if adequately and consistently given, is valuable. Outside of contrast baths, exercises and whirlpool baths, the most helpful device is the electric cradle, which must be used continuously at night, and, in acute cases, day and night. The temperature should be around 100 degrees Fahrenheit. When the inflammatory reaction subsides with resulting stenosis or obliteration of the arteries and there is a demonstrable spasm of the collateral vessels, a sympathectomy may be considered. Of 20 cases only 3 were advised to have an operation: 1 refused, and in 2 the results have been indifferent.

The degenerative lesions, heavy plaques of the intima, calcified stenotic vessels, can naturally not be influenced. Much can be accomplished, however, by increasing the motor power of the heart and raising the normal but previously high blood pressure to a level which insures enough inflow against the increased peripheral resistance. That, particularly in early cases, the prognosis is not bad is amply demonstrated by many observations, where gradual obstruction of the main arteries, in the presence of adequate cardiac function is followed by a compensation of the impaired circulation. In spite of absent peripheral pulse, the foot of such patients is warm, of normal color, and tolerates exercise.

Fig. 2. Blood vessel visualization in a patient with normal arterial tree. Note the cubital artery with the recurrent branches around the elbow, the radial interosseus and ulnar arteries. A large phlebolith is visible, medial to the radial artery.

Desensitization of the foot with alcohol injections into sensory nerves, has been practiced by Smithwick and White. We have only 2 patients in this series in whom this method was used. The sensory nerves are exposed above the ankle, below the point where they give their last motor branches, and injected with alcohol. Both patients obtained complete relief at the time, but both legs had to be amputated months later. The greatest objection to the method is that it destroys important collateral arteries along the

nerves and that the anæsthetic foot, which is usually gangrenous already, may be exposed to a great deal of injury and spreading infection.[1]

Morphine should be used as sparingly as possible. Sometimes one is able to improve circulation to a great extent, but meanwhile the patient has become a drug addict and will complain of pain for which there is no objective evidence.

When an amputation becomes inevitable, it should be urged with the greatest emphasis and executed under a low spinal anæsthesia at the proper level. The passive attitude of many physicians in regard to amputation, has caused a great deal of unnecessary suffering or even death.

### TREATMENT OF FUNCTIONAL VASCULAR OCCLUSIONS

When the cause of vascular spasm is found in definite irritative lesions, such as cervical rib, occult spina bifida, and amputation neuroma, the removal of these factors produces gratifying results. In patients with causalgia, following mild injuries, the decortication of the inflamed, hyperæmic nerve was followed by amazing improvement in 2 of our own cases. Some diseases of the central nervous system, such as tabes, syringomyelia, may exhibit visceral or peripheral vascular spasms. These findings, together with attacks of crises may necessitate the advice and cooperation of the neurologic surgeon. Early cases of hypertension sometimes complain of "rheumatic" pains in the muscles, cramps in the calves, as a symptom of vessel spasm. In such patients a thorough medical examination is indicated. Young women before puberty and women near the climacteric may exhibit marked vasomotor irritability; if the basal rate is low, adequate thyroid medication has been found almost specific, although the disturbance is probably pluriglandular.

Most important are local anatomical changes in the vessel wall that produce reflectoric spasms in the same vessels and in the collaterals. We have already touched on this problem in discussing the treatment of Buerger's disease. When we regard Buerger's disease as a sensitization of the entire vascular system to some unknown and perhaps non-specific agent, the logical treatment is to quiet down this allergic reaction, and then, in a completely quiescent stage, if there is still demonstrable vessel spasm in the new collaterals, perform a sympathectomy. These obliterated, healed arterial segments act as a nerve plexus and a continuous source of abnormal vascular reflexes. Removal of such obliterated arterial segments has been suggested. We have had no experience with it.

The diagnosis of a true, idiopathic angiospasm, Raynaud's disease can be made only when all secondary forms of spasms have been excluded. The mild cases may be treated with conservative measures of physiotherapy and vasodilators. But in the progressive forms, sympathetic ganglionectomy effects a real clinical cure. In fact, we believe that when Raynaud's disease is not benefited by sympathectomy, the diagnosis must be revised and a secondary type of spasm searched for. While there is a great deal of controversy as to the peripheral, local, or a central cause for spasm in Raynaud's disease, the clinical results with such an operation are most striking. That the results are not equally satisfactory in the hands of some surgeons may be due to (1) improper selection of cases, (2) incomplete operations.

While technical details have no place in this paper, of the many approaches suggested in the literature, we prefer an extraperitoneal approach through the anterior abdominal muscles to the lumbar sympathetic chain. Following the removal of the chain the result is noted, the other limb being used as a control, and only if the results are definite is the other chain removed.

For the cervicothoracic sympathectomy, which requires the removal of the stellate, first and second thoracic ganglia, the posterior approach with resection of the first and second rib and transverse process is used. Here again only one side should be removed at the first operation, and careful postoperative study should determine whether the operation is worth while.

That an absence in improvement is not due to the fault of the method can be illustrated by stating that chains of lymph vessels, lymph glands, fibers of the endothoracic of prevertebral fascia have been taken for the sympathetic chain. Therefore, a histological control of the removed specimen is important.

In the vasodilator disturbances, polycythæmia must be first excluded (2). Secondary vasodilatations, just as secondary vascular spasms, are much more frequent. The improvement of the blood picture in treated polycythæmia is followed by relief from the burning pain in the extremities. In the true erythromelalgia, which is very rare, radium packs seem to offer the most relief. In acrocyanosis, a paralysis of the small venules is said to exist (16). The disease is not painful or progressive, but rather disturbing to the patient. Our personal observations would suggest a pit-

[1] Very promising results have been obtained with intermittent negative pressure by Reid and Herrmann. This method may revolutionize the conservative treatment of obliterative vascular disease.

itary disturbance, but because of the impossibility to administer active preparations by mouth, we have not drawn any therapeutic conclusions.

SUMMARY

This brief outline of peripheral vascular disturbances illustrates the large number of etiological factors that have to be considered in order to arrive at adequate therapeutic measures. These patients are not medical or surgical cases. They may require orthopedic, ophthalmological or neurologic study. Only the combined effort of group study will result in accurate diagnosis and successful treatment.

BIBLIOGRAPHY

1. ADSON, W., and COFFEY, J. R. Cervical rib. Ann. Surg., 1927, lxxxv, 839.
2. BARKER, N. W. Polycythemia vera and chronic pulmonary disease. Arch. Int. Med., 1931, xlvii, 94.
3. BROWN, G. E. Erythromelalgia and other disturbances of the extremities, accompanied by vasodilatation and burning. Am. J. M. Sc., 1932, clxxxiii, 468.
4. BUERKLE-DE LA CAMP, H. Blutgefaessdarstellung bei gefaessverengerenden Vorgaengen. Arch. f. klin. Chir., 1932, clxxiii, 799.
5. Bulletin of the United States Bureau of Labor Statistics, No. 236, Washington, 1918.
6. DE TAKATS, GEZA. The cutaneous histamine reaction as a test for collateral circulation in the extremities. Arch. Int. Med., 1931, xlviii, 769.
7. Idem. The differentiation of organic and spastic vascular occlusions. Ann. Surg., 1931, xliv, 321.
8. Idem. Vascular anomalies of the extremities. Surg., Gynec. & Obst., 1932, lv, 227.
9. DITTRICH, R. J. Lumbosacral spina bifida occulta. Surg., Gynec. & Obst., 1931, liii, 378.
10. GRUBER, G. B. Endarteritis obliterans and Kaeltebrand. Beitr. z. path. Anat., 1930, lxxxiv, 155.
11. HELLMUTH, MARGOT. Ueber Gefaessveranderungen bei der Frostgangraen. Arch. f. klin. Chir., 1930, clviii, 702.
12. JAEGER, ERNST. Zur pathologischen, Anatomie der Thromboangiitis obliterans bei juveniler Extremitaetengangraen. Virchow's Arch. f. path. Anat., 1932, cclxxxiv, 526.
13. JOHNSON, C. A. Studies on peripheral vascular phenomena. Surg., Gynec. & Obst., 1932, lv, 731.
14. KAUNITZ, JULIUS. Chronic endemic ergotism; its relation to thromboangiitis obliterans. Arch. Surg., 1932, xxv, 1135.
15. KUETTNER, H., and BARUCH, M. Traumatischer, segmentarer Gefaesskrampf. Beitr. z. klin. Chir., 1920, cxx, 1.
16. LAYANI, F. Les Acrocyanoses. Paris: Masson et Cie, 1929.
17. MCKITTRICK, L. S., and ROOT, H. F. Diabetic Surgery. Philadelphia: Lea and Febiger, 1928.
18. SAMUELS, S. S. New diagnostic sign in thromboangiitis obliterans. J. Am. M. Ass., 1929, xcii, 1571.
19. SMITHWICK, R. H., and WHITE, J. C. Elimination of pain in obliterative vascular disease of lower extremity; technique for alcohol injection of sensory nerves of lower leg. Surg., Gynec. & Obst., 1930, li, 394.
20. V. BERGMANN, G. Funktionelle Pathologie. Berlin: Julius Springer, 1932.
21. WHITE, PRISCILLA. Diabetes in Childhood and Adolescence. Philadelphia: Lea and Febiger, 1932.

# EDITORIALS

## SURGERY, GYNECOLOGY AND OBSTETRICS

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MARCH, 1934

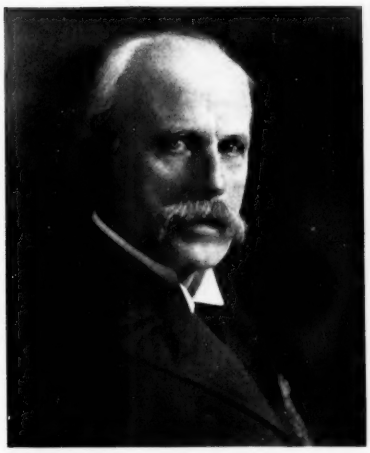
### A HALF CENTURY OF SERVICE TO SURGERY

THE present year marks the completion of fifty years of publication of the *Annals of Surgery* under the continuous editorial supervision of Lewis Stephen Pilcher.

Without historical perspective no one can appreciate the service this journal has rendered to the advancement of surgery. Its first number appeared in 1885 at the beginning of the evolution in medicine initiated by the discovery of bacteria; consequently, its pages have recorded the resultant kaleidoscopic changes in surgical practice. While the thoughtful surgeon will not have the temerity to maintain that no subsequent five decades will equal those just passed yet it cannot be denied that this period spanned by the publication of the *Annals* has encompassed more advance than any five centuries that preceded it. Lister published in 1867 his contribution on "The Antiseptic Principle in the Practice of Surgery" and in 1880 introduced the catgut ligature for tying blood vessels, but his ideas were subject to ridicule and his principles slowly accepted. Aseptic surgery was just beginning to be practiced in 1884. It was not until 1886 that Von Bergmann changed from corrosive sublimate to steam sterilization and not until 1891 that he had fully developed his aseptic technique. That American surgery was already embarked on its practice is seen when we read in the first number of the *Annals* in an editorial survey of the previous years' surgery by the pen of its editor, "One of the most prominent features of the yearly progress in American surgery is the increasing use of antiseptic methods and appliances.... Although opinions vary as to the ultimate truth of the theories of antiseptic surgery, yet few venture to deny the benefits from its practice." Pilcher himself went farther in a paper read that same year and urged the use of "aseptic instruments so constructed as to leave no crevices or joints where impurities may find lodgement" and advocated buried catgut sutures "by which the layers of the tissue, one after another, are apposed from the bottom of the wound upward." It must not be forgotten that it was only in 1880 that Pasteur had identified the staphylococcus and streptococcus and that chairs of bacteriology were established in Munich and Wiesbaden.

Under the protection of this new principle every part of the body began to be invaded by the adventurous surgeon and it is this revolution and development that the turned pages of the *Annals* reveal throughout its fifty years. While previously advances had been made they were largely in fields in which aseptic surgery was not imperative, although here and there bold surgeons had begun abdominal surgery. In 1881, Billroth had su-

cessfully resected the pylorus for cancer, Wolfer had introduced gastro-enterostomy, and Hahn had performed nephrectomy.



Lewis Stephen Pilcher

The *Annals*, at its inception, had the distinction of being the first journal in the English language devoted exclusively to surgery, and under the editorship of Pilcher and his English associate, Keetly, it attracted the principal contributions of both American and English surgeons. Among those appearing in the first volume we read the names of Fenger, Gibney, Park, Senn, and Wier, of the United States; Fenwick and J. Hutchinson, of England; and Shepherd, of Canada. Here appear Parkes' great article upon "Gunshot Wounds of the Small Intestine" and Roswell Park's "Fat Embolism." In the seventh volume we find Senn's monumental contribution on intestinal obstruction and resection. Crile appeared in 1891 and William Mayo in 1893. The list of its contributors during this half century is the roll call of America's greatest surgeons. To maintain a journal through fifty years upon such a plane, to admit nothing cheap and tawdry, to insist upon scholarly presentation and scientific truth in all contributions, to have served so efficiently the changing science of surgery, requires an editor with courage, culture, scientific attainments, and ideals. To Lewis Stephen Pilcher American surgery owes a great debt.

ALLEN B. KANAVEL.

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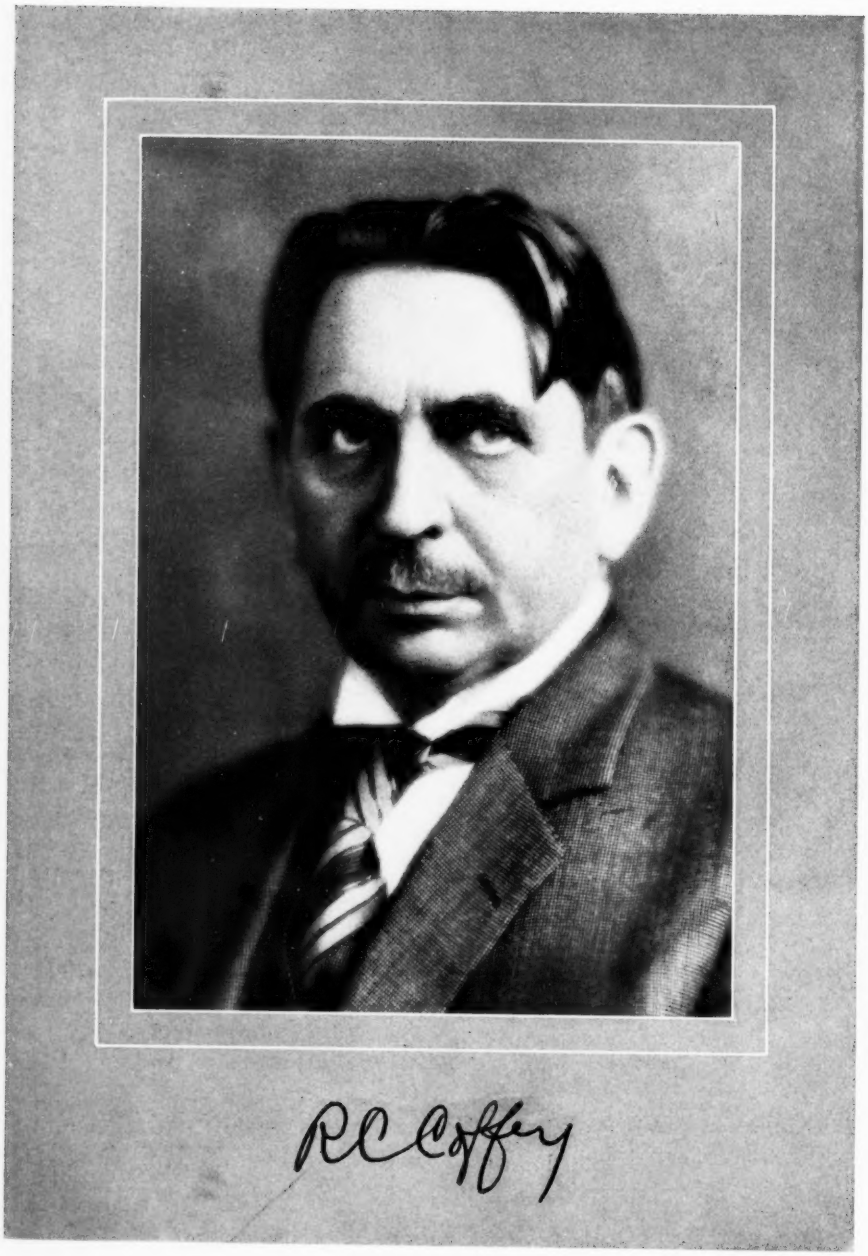
## THE ROUTINE EXAMINATION OF PERIPHERAL BLOOD VESSELS

THE tremendous amount of study which has been devoted to the question of the peripheral vascular diseases during the past few years has resulted in the accumulation of a mass of valuable data. One important result of the study is the knowledge which leads us to believe that there are thousands of people who have advanced peripheral vascular disease and never have any impairment of function which brings them to consult a doctor. The result of this is an increasingly conservative attitude in the treatment of patients who develop gangrene or symptoms from their peripheral vascular disease. For the past 15 years the treatment of the condition known in this country as thromboangiitis obliterans, or Buerger's disease, has gradually become more conservative. Considerable impetus to the conservative treatment was given by Meleny and Miller in 1925 when they showed the great tendency for the spontaneous development of a collateral circulation in this disease. Their studies also showed that there was not the same tendency in cases of arteriosclerosis. Their work has been amply confirmed. Unfortunately, and perhaps as a result of their study of the collateral arteries, there has remained a more or less hopeless attitude concerning the treatment of arteriosclerotic conditions of the extremities. Recent studies seem to indicate that this is the wrong attitude and that with proper treatment the arteriosclerotic patients

can often establish a circulatory balance which will allow them to resume useful and active occupations without the necessity of amputation. In the Vascular Disease Clinic at the Cincinnati General Hospital we are adopting just as conservative treatment for arteriosclerotic patients as for any other type of organic arterial disease.

Another important outcome of the recent intense interest in peripheral vascular diseases is the great importance of recognizing these conditions early, and the institution of measures which will materially reduce the incidence of those accidents which often result in processes with which the reduced circulation cannot cope and which may require amputation of the extremity. The simple measures of warmth to the feet, avoidance of injury and infection, the care of the skin, vascular exercises, and the optimum level of the resting extremity have been repeatedly stressed. Recently there has been a revival of interest in the use of an intermittent negative and positive environmental pressure as a means of promoting the establishment of an active collateral arterial circulation.

Now it becomes an important duty to teach the medical profession to examine all of the peripheral pulses and to endeavor to estimate the vascular sufficiency, particularly of the legs, in the routine examination of all patients. The preventive measures applied as a result of these studies will undoubtedly lessen materially the serious surgical conditions which are now arising from unrecognized peripheral vascular disease. MONT R. REID.



R C Coffey

UNIV. OF IOWA

# MEMOIRS

## ROBERT CALVIN COFFEY

WE think of pioneers in relation to the development of the material resources of a new country, subduing a wilderness of forests and plains, but there have always been spiritual pioneers who despite the unaccustomed surroundings of a primitive country, through their own resources develop a genius for meeting human problems.

So Dr. Robert Calvin Coffey with romantic zeal organized himself, if one may so speak of it, because his campaign was individualistic, and not only in pioneer days but all his life attacked surgical problems which had tried the courage and resources of the best men in the surgical profession from the time that surgery began to do its part in alleviating the miseries of mankind. Large in mind, in body, he was great in courage and in desire to help those who appeared doomed to a life of misery or to untimely death.

We think with admiration of the Cavaliers, who came into Virginia and the Carolinas and Georgia, and who themselves or through their descendants influenced so greatly the material, social, and spiritual development of America and left indelible impress on scientific progress—Ephraim McDowell, J. Marion Simms, W. E. B. Davis, and many others.

Dr. Coffey was born October 20, 1869, in Caldwell County, North Carolina. He received his education in the local schools, attended the Globe Academy, and later went to Kentucky, where in 1892 he was graduated from the Kentucky School of Medicine at Louisville.

On graduation from medical school, Dr. Coffey started practice in Moscow, a small town in the mountainous district of northern Idaho. A year later he returned east to Junction City, Kansas, to marry Miss Clarissa Ellen Coffey, who recently had moved to Kansas with her parents from Lenoir, North Carolina, and who was of the same stock as himself, with the same basic education and the same ideals for living. After they were married, they traveled on together to Moscow. And to this fine woman, wise as few women are wise, he owed much of his success.

His work in Idaho was that of a country practitioner doing a moderate amount of general surgery, but he was laying the foundation for the splendid work, in

that early day largely experimental, which resulted so greatly for the benefit of surgery. In 1900, he moved to Oregon and settled in the beautiful city of Portland, which was to become one of the great cities of the Pacific Coast. There was at that time in Portland a hospital which had been operated by a group of citizens and which had been unsuccessful. Dr. Coffey told me that the owners were so glad to get rid of the hospital that they did not inquire whether or not he had the money to pay for it, and he was so glad to get something to do that he was more than willing to accept the responsibility.

Although Dr. Coffey had visited us in Rochester on several occasions, I first met him, really to know him, in 1905, at the annual meeting of the American Medical Association in Portland. At that time he chartered a steamboat and took about two hundred of us on a beautiful ride on the Columbia River and one of its wide tributaries. It was a great group of men on the boat that day, from Chicago, Boston, New York, Philadelphia, and all parts of the country. Too generous in his hospitality to count the cost of the boat trip, Dr. Coffey on that occasion unconsciously made us aware of his capabilities and of the many ideas he had in mind for scientific progress.

Too poor in those early years to develop such a laboratory as he needed, his experimental work was carried out with small equipment and little aid. He attacked one surgical problem after another.

Dr. Coffey was markedly individualistic, but as time went on he gathered around him in Portland a fine group of men who were devoted to him, developed an excellent modern hospital, and consistently played a great part in the development of surgery, not only in the Northwest, but of America and the world. He was in constant attendance on medical society meetings in all parts of the country and abroad, and he always contributed to the success of the meetings, presenting papers on subjects that had baffled the profession. Always welcomed by his confrères abroad, Dr. Coffey on his last visit to Europe, not long before his death, was received with signal honor in recognition of his great contributions to surgery.

I shall not go into the details of Dr. Coffey's contributions to surgical progress, for instance, the removal of the head of the pancreas and the joining of the pancreatic duct and the duodenum; the transplantation of the common bile duct into the duodenum; the extirpation of the urinary bladder for carcinoma; radical procedures for the removal of carcinoma of the rectum and the lower sigmoid. His work on the transplantation of the ureters into the sigmoid and rectum, which he carried out with success, was classic. This operation has been adopted by surgeons throughout the world, making it possible at last for the miserable unfortunates born with exstrophy of the bladder and those with incurable leaking fistulas of the bladder to be restored to well-being and enabled to take up their life work.

With his zest for living and accomplishing, Dr. Coffey was a man who might not have been able to grow old cheerfully, and time is inexorable. It perhaps would have been difficult for him to adapt himself to the limitations brought by years, to accept the demands of the new generation, seizing opportunity to develop a world of their own. When travel by airplane came into operation, he welcomed it with great enthusiasm. It fitted in with the mind and spirit of the man, it was conquering new things. And when death came to him at the age of sixty-four as the result of an airplane accident, tragic end to a great life, he was, after all, leading on as ever, a pioneer in a new field of scientific progress.

WILLIAM J. MAYO.

# THE SURGEON'S LIBRARY

## REVIEWS OF NEW BOOKS

IN his excellent book[1], Cockayne has compiled in one short volume practically all of the facts that are known about the inheritance of skin diseases. The purpose of the book is twofold: first, to stimulate dermatologists not only to collect and publish information about families with inherited defects but also to report isolated examples of the same defect; for one of the facts about which we are almost entirely ignorant is the ratio of the isolated cases of a defect to the family group.

The second object of the book is to enable geneticists to see by the data given what defects are suitable for further study. They can then collect more information to elucidate some special problem.

There are fifteen chapters. The introductory chapter reviews the subject of Mendelian inheritance. The other chapters are devoted to physiological abnormalities, metabolic errors, errors of development of elastic tissue, dyskeratoses, ectodermal dystrophies, abnormalities of the teeth and nails, disorders of growth, vasomotor abnormalities, and dental anomalies associated with major disorders of development.

For the average medical reader, the first chapter reviewing the subject of Mendelian inheritance is apt to be a difficult one to follow. The remaining chapters, however, make most interesting reading. There are only a few illustrations, but the pages of the book are full of interesting family diagrams.

The bibliography is very complete and is sufficient evidence of the large amount of painstaking work the author has expended on this book. It is a book that every dermatologist and every physician interested in genetics should have on his shelves. We heartily recommend it.

EDWARD A. OLIVER.

IT was the original purpose of Clephan and Hill to prepare an elementary handbook on radium[2] for the needs of the nursing and technical staff working in connection with the radium therapy. As the work progressed, it seemed advisable to expand the subject and thus make it possible for the book to serve a wider purpose. The preparation of the booklet was undertaken at the suggestion of Professor Russ who has written the introduction.

The histological aspects dealing with the discovery of radio-activity and radium form the introductory chapter. The physical properties of radium are presented briefly. There follow chapters upon the principles of radium therapy, methods of applying radium and radon, and the complications and contra-indications of radium therapy.

The principles and results of treatment of cancer of the buccal cavity, rectum, breast, uterus, and skin as practiced in various American and European clinics are discussed. A detailed description of the construction of radium needles and tubes and a discussion of the care and precaution in handling radium are particularly useful.

This presentation is one of the best of several recent attempts to review the principles and technique of radium therapy concisely in a small volume. The subject is presented in a clear and accurate manner. To physicians who are interested in gaining a brief and accurate statement of radium therapy this little volume is highly recommended.

MAX CUTLER.

IN a volume of 434 pages[3], Foeldes discusses the fluid and mineral equilibrium in the body as understood today, and considers rather extensively the disorders in the body which have fluid and mineral retention as their theoretical etiological factor. Foeldes believes that epilepsy, eclampsia of pregnancy and infancy, migraine, angina pectoris, asthma, allergic diseases, gout, hypertension, pernicious anæmia, polycythæmia, acne vulgaris, nervous and psychic disturbances have water and salt retention as a common factor in the causation of symptoms. Certain constitutional changes and aging are likewise attributed in part to faulty fluid and mineral balance. The book is filled with citations to clinical observations and experimental work which support the author's views.

The production of epileptic attacks considered to be due to temporary accumulation of fluids constitutes a basis for a rational therapy, the aim of which is the prevention of retention and mobilization of water and minerals. Eclampsia is presented as essentially the same problem of storage and cortical irritation, and it is possible to regulate this state in a manner which prevents retention and the plan can be followed out over long periods of time. The author feels that the same pathogenesis and therapy is indicated in migraine. Exudative diathesis,

[1] INHERITED ABNORMALITIES OF THE SKIN AND ITS APPENDAGES. By E. A. Cockayne, D.M., F.R.C.P. 1st ed. London: Oxford University Press, 1933.

[2] AN ELEMENTARY HANDBOOK ON RADIUM AND ITS CLINICAL USE. By D. F. Clephan and H. M. Hill. London: Oxford University Press, 1933.

[3] A NEW APPROACH TO DIETETIC THERAPY. METABOLISM OF WATER AND MINERALS AND ITS DISTURBANCES. By Eugene Foeldes, M.D. Boston: Richard C. Badger, 1933.

rickets, and eclampsia of infancy seem to be different manifestations of similar water and mineral retention in the infant. The author discusses fluid retention which is noted after meals, in low temperatures, on exercise, and on lying flat, all of which bring on attacks of angina pectoris. Allergic diseases are attributed to a basis of general predisposition and retention of fluids. A vicious cycle consisting of retention of liquids with contraction of small arteries explains hypertension. The pathogenesis of primary anæmia is presented as achlorhydria and retention of fluids and swelling resulting in increased hæmolysis.

The author discusses constitutional types which are underlying factors in the production of these disorders: the aqueous type being one which has a tendency to store water and salts; the salinous constitution is the second type and it is characterized by retention of salts but not with great amounts of water and it is commonly met in people with decreased elimination of hydrochloric acid by the stomach. The hirudine constitution is distinguished by an instability of the water and mineral content of the organism while the euhydric type is considered the optimal balance.

All of these conditions are treated by an antiretentional diet which has no specific qualities but generally consists of a "liberal amount of proteins and nucleoproteids, a moderate restriction of carbohydrates, a severe restriction of fats, a restriction of liquids, and a free utilization of the natural sources of all vitamines." Mineral intake is not emphasized. M. HERBERT BARKER.

"THE purpose of this volume is not to present a treatise on any part of the broad field of urography but rather to emphasize the need for close correlation between the urologist and the roentgenologist and to show by the actual reproductions of many films what the roentgenologist may expect to find in the presence of various lesions and to indicate the proper interpretation of the shadows which are present."

Despite the wealth of urographic material which is to be found in recent texts on urology and radiology the work of Lower and Nichols[1] offers additional valuable information on all the roentgenographic problems of urinary tract diagnosis. A brief, but sufficiently comprehensive, history of the development of various phases of urography is given. The important points in the roentgenographic examination of the urinary tract are stressed. Examination of the male urethra, bladder, ureter, and kidneys is discussed in a clear, concise manner, and valuable points in technique and mode of interpretation are properly emphasized. A most instructive chapter deals with the indications for a roentgenographic examination of the upper right abdominal quadrant. The following 371 pages comprise an atlas of excellent roentgenograms with accompanying case history summaries of a most instructive nature. Special attention is given to urethrography, a rather neglected field, and cystography. Intravenous and retrograde pyelography is discussed in detail and many illustrations serve to depict the outline found in every type of urinary pathology. This volume deserves the attention of urologists in general both for thorough academic instruction and as a text for continued reference. VINCENT J. O'CONOR.

THE fourth volume of *The Practitioners' Library of Medicine and Surgery*[2] is a consideration of non-traumatic surgical conditions. The book is a compilation of material written by twenty authors and covers discussions on local infections, neoplasms in general, regional surgery, and surgery of the various glands of the body. The book is arranged systematically, is concisely written, although some of the chapters appear sketchy. The volume is profusely illustrated, which is a great boon to the average practitioner for whom this volume is intended. All in all, a wealth of material is covered and should be a valuable addition to a surgical library.

The chapter on surgery of the pericardium, heart, and the great blood vessels by Beck is worthy of especial commendation. It brings forth, in a comparatively few pages, our present knowledge of this important and most interesting surgical specialty. Another interesting chapter worthy of consideration is that by Wangensteen on diseases of the peritoneum, mesentery, and omentum. His postoperative treatment of peritonitis is especially interesting, in which he recommends the introduction of a Levin tube passed through the nose, with the employment of suction as obtained by water siphonage whereby distention is eliminated and vomiting disappears. Koontz's chapter on hernia offers more, perhaps, than most textbooks or systems covering this very important branch of surgery. Koontz's discussion on sliding hernia is a welcome addition, as this very interesting type of hernia is generally given little prominence in most textbooks. The chapters covering the surgery of the gastrointestinal tract are rather brief. It must be said, however, that only the meat has been preserved, all superfluous material having been eliminated.

On surgery of the prostate gland, although this volume is published in 1933, one sentence makes mention of "the burning of a tunnel through the obstructing adenoma with specially designed instruments in certain selected cases." The chapter on surgery of the pancreas is not extensive, giving rather a sketchy bird's eye view of diseases of this organ.

This book represents a tremendous amount of work and effort and is a welcome addition to one seeking worth while information in the tremendous field of non-traumatic surgery. EARLE I. GREENE.

[1] ROENTGENOGRAPHIC STUDIES OF THE URINARY SYSTEM. By William E. Lower, M.D., F.A.C.S., and Bernard H. Nichols, M.D., F.A.C.R. St. Louis: The C. V. Mosby Company, 1933.

[2] THE PRACTITIONER'S LIBRARY OF MEDICINE AND SURGERY. VOL. IV—NONTRAUMATIC SURGERY. New York and London: D. Appleton and Company, 1933.

THE third edition of Boyd's *Surgical Pathology*[1] presents a number of additions and revisions. The additions include brief sections on the metabolism of tumors, chronic follicular gastritis, high temperature deaths following cholecystectomy, non-obstructive hydronephrosis and autolytic peritonitis. Among the sections which have been altered or entirely rewritten, are those on the action of radium on tumors, secondary jejunal ulcer, acute intestinal obstruction, cholesterolosis of the gall bladder, varicose veins, and osteitis fibrosa. The general form and character of previous editions has been preserved. Thus the choice of material is confined to "those aspects of pathology which will prove useful to the surgeon." There is a constant effort to correlate anatomical changes with alterations in function and the resultant clinical manifestations. The method of presentation is uniformly direct and compact. Consequently, the book yields much information of genuine interest to the practicing physician and is easily read. In the handling of controversial subjects opposing views are briefly presented and the author is neither dogmatic nor evasive in his conclusions. Thus in the section on the thyroid gland Rienhof's view of the origin of nodules is accepted on its merits; and the author states with refreshing directness that "the more one studies the problem of goiter the more one is convinced of the mistake of separating toxic adenoma from exophthalmic goiter." The difficult controversy on the significance of chronic mastitis as a precancerous lesion is succinctly but adequately handled. On this question the author is inclined to accept the views of Bloodgood as opposed to those of Ewing and Cheatle. With few exceptions the literature has been brought well up to date. One might perhaps regret that in the discussion of the theories of shock no mention is made of some of the more recent work on the subject, particularly that of Blalock and his associates.

In general the book should serve a very useful purpose to students, internists, and surgeons. With relatively little overlapping it fills in the gap between works on the purely anatomical and the purely clinical aspects of disease. LAWRENCE JACQUES.

THE book on blood transfusion by Dr. Wildegans[2] gives a concise general review of the subject of transfusing blood. The entire subject is treated very well under six chapters which are adequately illustrated.

After a brief historical account, the problem of blood grouping is considered. The various classifications of blood groups are given and the classification recommended by v. Dungern and Hirszfeld is considered in detail. The chief discussion pertains to the hereditability of the blood characteristics and contends that the structures of A and B corpuscles never appear in the offspring unless they are present in one or both parents. The remainder of the chapter deals with the agglutination and hæmolysis of red blood corpuscles, and various recommendations are given for differentiating between true and pseudo-agglutinations.

In the selection of donors the importance and necessity of preliminary cross-agglutinations is emphasized. The indirect methods (employing known test sera) and direct methods (employing cell suspensions and sera of recipient and prospective donor) are given in detail. Emphasis is attached to the importance of carrying out these tests before each transfusion of blood.

The effect and fate of the transfused blood are also dealt with in a special chapter. Attention is called to the fact that the medium by which a transfusion of blood exerts its favorable influence is still a moot question. It is suggested that the beneficence of a blood transfusion may be attributed to the preservation of the transfused red blood cells, to recuperation, or to a rapid new formation of blood corpuscles in consequence of the stimulus exerted on the hæmatopoietic organs.

Under technique the direct and indirect methods of transferring blood are discussed in detail. In addition acceptable methods are given for transfusing infants and small children.

As indications, the various medical and surgical conditions entailing a loss or impoverishment of one or more blood elements are enumerated. The contra-indications are given as absolute and relative. Organic heart disease with decompensation and acute cardiac dilatation are given as absolute contra-indications. The relative contra-indications, where caution is to be exercised in transfusing blood, are pregnancy, pneumonia, and severe bronchitis, diseases of the kidneys with oliguria, thrombosis, and thrombophlebitis, and a state of marked cachexia.

Finally, the cases in which severe and fatal reactions occur are considered. The author repeatedly emphasizes that fatalities can almost without exception be avoided by carefully and accurately carrying out the necessary preliminary blood typing and cross-agglutination tests. E. E. BLANCK.

THE first edition of Holt's *Diseases of Infancy and Childhood*[3] was published in 1897, when pediatric knowledge was in a nebulous stage. Throughout the succeeding years as greater and greater advances have been made in every branch of medicine this standard textbook has been revised to keep abreast of the "rushing stream of medical progress." Throughout this period this textbook has been accepted as a standard by a generation of teachers and students. It has probably taken no small amount of courage on the part of the present revision authors to make as complete a revision of this text as they have undertaken. Eight sections have been rewritten and

[1] SURGICAL PATHOLOGY. By William Boyd, M.D., M.R.C.P.(Ed.), F.R.C.P. (Lond.), (Dipl. Psych.), F.R.S.C. 3d ed. Philadelphia and London: W. B. Saunders Company, 1933.

[2] DIE BLUTTRANSFUSION IN THEORIE UND PRAXIS. By Dr. Med. Hans Wildegans. Berlin: Julius Springer, 1933.

[3] HOLT'S DISEASES OF INFANCY AND CHILDHOOD; A TEXTBOOK FOR THE USE OF STUDENTS AND PRACTITIONERS. By the late L. Emmet Holt, M.D., and John Howland, M.D. Revised by L. Emmet Holt, Jr., M.D., and Rustin McIntosh, M.D. 10th ed. New York: D. Appleton and Company, 1933.

new articles added. No radical departures have been made in the general plan and structure of the text. The book still gives one the impression of the old text but with a difference. There is a greater simplicity of description noticeable throughout but nowhere better illustrated than in the chapter on artificial feeding. A simple isocaloric formula, isocaloric with breast milk, is the basis upon which feeding formulas are built. There are just enough reservations and explanations made to this method of feeding for the student reader to know that not all babies will thrive on such a formula and yet not leave him confused by a multiplicity of formulas.

In line with most recent textbooks, a bibliography has been added at the end of each chapter. This of course makes it possible for those interested to read the original articles on the subject described.

There is little doubt that even the critically minded reader will find this book has maintained the high standard set by the deceased senior authors. In all probability it still will be the recommended textbook by the majority of teachers of pediatrics.

GERARD N. KROST.

THE book on *Internal Derangements of the Knee-Joint* by Timbrell Fisher[1] is a most excellent monograph. It shows a vast amount of careful study of clinical, pathological, and experimental material. The anatomy is brief and clear and the illustrations excellent. The physiology of the semilunar cartilages is carefully treated and the possibility of regeneration from an experimental and clinical standpoint is considered. The symptomatology of the various divisions of the subject is systematically handled. The classification of loose bodies in the joint and the illustrations of the various forms are clear and understandable. The origin of these bodies is discussed from a clinical and pathologic standpoint, as well as from an experimental standpoint.

In conclusion I would state that this book merits very thorough study and should be in the library of every general surgeon. WILLIAM R. GUBBINS.

THE book entitled *Massage and Remedial Exercises*[2] was written as a textbook on massage and remedial exercises. The use of massage and exercises in the treatment of injuries is well described. The chapter on the use of exercises in the treatment of stiff joints is worthy of the attention of everyone treating these difficult conditions.

The author in advising passive movements makes it clear whether relaxed or forced movements are to be used. The term "passive movement" has been a source of misunderstanding in the past, as the term passive movement has been used for both relaxed and forced movements. The only true passive movement is a relaxed one.

In order to consider all the subjects for which massage and exercises have been recommended, many conditions are included in which massage and remedial exercises have few indications: for example, hæmorrhoids, chronic tonsillitis, enteritis, and cirrhosis of the liver. These might profitably be omitted, and more illustrations added.

As a whole the work is a valuable textbook for those interested in massage and exercise, and could well be used by physicians as a reference book in prescribing exercises. GERTRUDE BEARD.

[1] INTERNAL DERANGEMENTS OF THE KNEE-JOINT; THEIR PATHOLOGY AND TREATMENT BY MODERN METHODS. By A. G. Timbrell Fisher, M.C., M.B., Ch.B., F.R.C.S.(Eng.). 2d ed. New York: The Macmillan Company, 1933.

[2] MASSAGE AND REMEDIAL EXERCISES; IN MEDICAL AND SURGICAL CONDITIONS. By Noël M. Tidy. Baltimore: William Wood and Company, 1933.

# BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

TRANSACTIONS OF THE AMERICAN SURGICAL ASSOCIATION. Vol. li. Edited by Walter Estell Lee, M.D. Philadelphia: J. B. Lippincott Company, 1933.

MENTAL HYGIENE IN THE COMMUNITY. By Clara Bassett. New York: The Macmillan Company, 1934.

THE PRACTICE OF SURGERY. By Russell Howard, C.B.E., M.S. (Lond.), F.R.C.S. (Eng.), and Alan Perry M.S. (Lond.), F.R.C.S. (Eng.). 4th ed. Baltimore: William Wood & Company, 1933.

NEUROLOGY. By Roy R. Grinker, M.D. Springfield, Illinois, and Baltimore, Maryland: Charles C. Thomas, 1934.

OPERATING ROOM PROCEDURE; FOR NURSES AND INTERNES. By Henry C. Falk, M.D., F.A.C.S. With a Foreword by Eugene H. Pool, M.D. New York and London: G. P. Putnam's Sons, 1934.

NATURE, M.D. HEALING FORCES OF HEAT, WATER, LIGHT, ELECTRICITY AND EXERCISE. By Richard Kovács, M.D. New York and London: D. Appleton-Century Co., 1934.

DIE GEBURTSVERLETZUNGEN DES KINDES. By Prof. Dr. Hans Naujoks. Stuttgart: Ferdinand Enke, 1934.

VERSUCHE EINER DEUTUNG DER PATHOGENESE DER SKELETTVERÄNDERUNGEN BEI CHONDRODYSTROPHIA FOETALIS (Kaufmann). By Åke Wilton. Copenhagen: Levin & Munksgaard, 1933.

GELENKSTEIFEN UND GELENKPLASTIK. By Prof. Dr. Erwin Payr. Vol. i—Pathologische Biologie der gelenke Pathogenese und pathologische Anatomie der Ankylosen; Klinik diagnostik und Anzeigestellung. Berlin: Julius Springer, 1934.

NEUROANATOMY; A GUIDE FOR THE STUDY OF THE FORM AND INTERNAL STRUCTURE OF THE BRAIN AND SPINAL CORD. By J. H. Globus, B.S., M.D. 6th enl. rev. ed. Baltimore: William Wood & Company, 1934.

LABORATORY MEDICINE; A GUIDE FOR STUDENTS AND PRACTITIONERS. By Daniel Nicholson, M.D. 2d rev. ed. Philadelphia: Lea & Febiger, 1934.

PATHOLOGIE UND KLINIK DER GRANULOSAZELLTUMOREN. By Dr. Walter Schiller. Vienna: Willhelm Maudrich, 1934.

THE PRACTITIONERS' LIBRARY OF MEDICINE AND SURGERY. Vol. v—Traumatic Surgery. Vol. vi—Obstetrics and Gynecology. New York and London: D. Appleton-Century Company, 1934.